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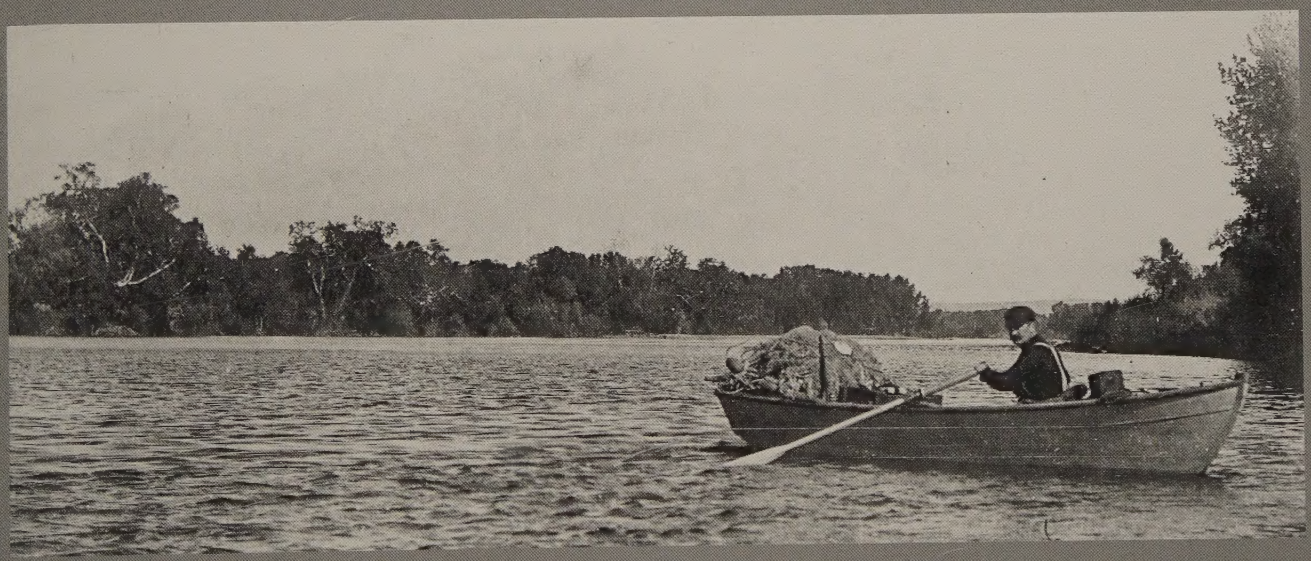

Cloudsley Louis Rutter
(1867–1903)

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On the cover:
Rutter in a skiff with fish sampling gear on the Sacramento River, California, in 1901. Photo Courtesy of Richard R. Rutter.

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Cloudsley Louis Rutter (1867–1903): Pioneer Salmon Biologist and Resident Naturalist, Fisheries Steamer *Albatross*

MARK R. JENNINGS

"...accomplish your work even if it is a little hard on others; as their assistance in a successful work will reflect credit on them as well as yourself."

Cloudsley Rutter (1903)[1]

Introduction

By the beginning of the 20th century, the United States Fish Commission (USFC) had reached a milestone long envisioned by its first Commissioner Spencer Fullerton Baird: an agency largely staffed with scientists well-trained in the field of fisheries biology and assisted, as needed, by a cadre of university professionals (Allard, 1978; Jennings, 1997a). From senior directors down to intermittent field assistants, a majority of USFC employees now had at least some college education from American universities. This was the result of nearly 3 decades of effort by a relatively small group of educators and government officials (Brittan, 1997).

This period was also the height of the Progressive Era, a time where great faith was placed in the notion that scientific investigation could solve many political, social, and economic problems, including the rapid destruction of the nation's natural resources (Hays, 1959). Its most important proponent was President Theodore Roosevelt who created a number of scientifically based government agencies and commissions, staffed them with college educated specialists, and ensured the passage of laws to remove "unqualified" employees from technical government positions (Hays, 1959; Nash, 1976).

It was during this Progressive Era that the USFC was deeply engaged in studying salmon, *Oncorhynchus* spp., and other important fisheries resources along the Pacific coast (Smith, 1910; Larkin, 1970). A number of dedicated professionals both inside and outside the USFC felt that they could restore declining and depleted salmon runs by taking a scientific approach to the problem, mainly by studying the life history and ecology of each species in the field, suggesting regulations to limit commercial fishing (or identify new fishing grounds), and building hatcheries to make up for the collapse of commercial salmon runs (McEvoy, 1986).

This policy required large amounts of field work and scientific data to

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[1]Rutter 1903. Unpublished personal diary of Cloudsley Louis Rutter during his 1903 Alaska trip. Original in possession of Richard R. Rutter [=RRR], Professor of Orthodontics, University of the Pacific, Arthur A. Dugoni School of Dentistry, San Francisco, Calif. An edited copy of the original diary is in the author's possession and is the subject of a future manuscript (M. R. Jennings, In prep.)

ABSTRACT—The meteoric career of Cloudsley Louis Rutter (22 Feb. 1867–29 Nov. 1903), an Assistant with the United States Fish Commission (USFC) (1893–94; 1897–1902), Curator of Ichthyology at the California Academy of Sciences (1900–02), and Resident Naturalist, Fisheries Steamer Albatross (1902–03), is described, and his many contributions to ichthyology and fisheries science are reviewed. As one of the first zoology students of David Starr Jordan and Charles Henry Gilbert at Stanford University, he pioneered life history studies of Pacific salmon, Oncorhynchus *spp., in California and Alaska, hatchery methods for sockeye salmon,* O. nerka, *in Alaska, and assisted in the study of sea lion,* Eumetopias jubata *and* Zalophus californianus, *predation of commercial fishes along the Pacific Coast.*

A gifted ichthyologist, writer, administrator, and collector of natural history specimens, he was responsible for designing and conducting many of the USFC field studies in the Far West at the turn of the century. His work on Chinook salmon, O. tshawytscha, *in California remains a classic in the field, and his other 30 publications over a 10-year period are important contributions to the ichthyology of China, the northeast Pacific, and the American West. Several of his publications remain useful today because they describe fishes and habitats that have virtually disappeared over the past century.*

Rutter was also innovative in the use of field photography for fisheries work, and he helped initiate studies in fish embryology, tagging, toxicology, and culture. He was apparently the first fisheries biologist to lament the widespread practice of introducing fishes from the eastern United States into California waters and the needless persecution of rainbow trout, O. mykiss, *and charr,* Salvelinus *spp., by commercial salmon fishermen in Alaska. However, he also strongly advocated the use of hatcheries to augment declining salmon runs, a policy that contributed to the subsequent extinction of number of races of trout and salmon along the Pacific Coast. His tragic death at the young age of 36 robbed the USFC of one of its best investigators. He is a paragon of modern research fisheries biologists and fisheries administrators of the 20th century.*

justify the position and needs of the USFC before Congressional appropriation committees and the commercial fishing industry. Thus, a steady stream of young, college educated employees was hired by the USFC to meet its ever increasing demands (Jennings, 1997a).

One such employee was Cloudsley Louis Rutter (Fig. 1), a recent graduate of Stanford University and a protégé of Barton Warren Evermann, Charles Henry Gilbert, and David Starr Jordan (Evermann, 1917; Jordan et al., 1930). In a brief, but highly distinguished career, Rutter not only became a leading authority on Pacific salmon in California and Alaska, but he also helped initiate studies in fish tagging, toxicology, and culture, as well as sea lion, *Eumetopias jubata* and *Zalophus californianus*, predation on commercial fishes. In 1900, he began his association with the California Academy of Sciences (CAS) and as Curator of Ichthyology, helped to professionalize its small but steadily growing fish collection and described several new fish species that came to his attention.

Acknowledged as one of the best workers and scientific minds in the USFC ([Mayer], 1904; Van Arsdale and Gerber, 1904; Greene, 1905; Evermann, 1921), his untiring efforts resulted in a number of important publications on the fishes of Arizona and California (Evermann and Clark, 1931). These seminal studies are still referred to today because of his ecological comments about so many native fishes which are now considered to be threatened or endangered (Minckley, 1973; Moyle, 2002). Indeed, except for some inaccurate comments about the salmon spawning process (Hedgpeth, 1941) and his false notion (see Rutter, 1904a) that hatcheries can restore diminished salmon runs (Black, 2003), virtually all of Rutter's careful biological observations appear to have withstood the test of time, and he continues to be cited for his original fisheries research and analyses (Dunlop et al., 2009).

Unfortunately, little is currently known about Rutter himself due to his tragic death from erysipelas at the age of 36, the destruction of most early records of CAS during the 18 Apr. 1906 San Francisco earthquake and fire (Leviton and Aldrich, 1997), and the lack of detailed obituaries by colleagues in scientific publications (Anonymous, 1903a, b; Bowers, 1905a; but see also [Mayer], 1904; and Chamberlain, 1904). In this biography, I present the major points of Rutter's life, by emphasizing his accomplishments with Stanford University, the USFC, the Alaska Packers Association, and CAS.[2]

Early Life

Childhood Years, 1867–1880

Cloudsley Louis Rutter[3,4] was born on 22 Feb. 1867 near Snake Creek in Barton Township, Gibson County, Ind., the eldest child of George Austin Rutter (12 Nov. 1841–27 Mar. 1917) and Hanna Jane (Emmerson) Rutter (9 Sept. 1841–8 Nov. 1903). His father was a carpenter and farmer who had served as a member of Company F, 42nd Regiment Indiana Volunteers, throughout most of the Civil War (Stormont, 1914). In later years, the elder Rutter served as a college trustee of Oakland City College, and as the constable and tax collector of Oakland City, Ind. (Stormont, 1914; Shirley, 1985). Although a man of limited schooling in the early subscription schools of Posey and Pike counties, Ind., he nonetheless instilled the importance of education and high moral standards in his children: Cloudsley, Dora Elda (Rutter) Holt (5 Feb. 1869–14 Oct. 1960), and Fanna Myrtle (Rutter) French (16 Dec. 1877–6 Jan. 1962).[5]

Figure 1.—Cloudsley Louis Rutter in his home at 1014 Golden Gate Avenue in San Francisco in 1903. Original photo courtesy of Richard R. Rutter.

Young Cloudsley Rutter was so weak and sickly at birth that some of his neighbors thought that he would not live very long. However, he proved to be a fighter and by the age of 3, was showing many of the traits (i.e., well behaved, bright, conscientious, and

[2]Acronyms used for sources cited in this work are as follows: California Academy of Sciences, San Francisco (CAS); Indiana State University, Terre Haute, (ISU); Indiana University, Bloomington (IU); Smithsonian Institution, Washington, D.C. (SI); Leland Stanford Junior University, Stanford, California (LSJU); and National Museum of Natural History, Washington, D.C. (USNM). Copies of original letters in the possession of RRR have been xeroxed and placed in the CAS Archives.

[3]All of the statements regarding Rutter's youth are based on a 28 Nov. 1909 [-11 Dec. 1909] letter from Dora Holt to Effie Rutter and her son Cloudsley Damon Rutter [written on the back of an 1891 college essay entitled "A Comparative Character Sketch of Solomon and David"]. This was written by Rutter while he was a student at Doane College (copy in CAS Archives).

[4]Rutter's full name has been a source of confusion over the years. Some publications list his official name as "Cloudsley M. Rutter" (Dean, 1917:371; Hedgpeth, 1941:144; Hubbs, 1964:58; Eschmeyer, 1990:613); apparently the result of a printer's error on the cover of a reprint of Rutter (1899). In an original, signed, complimentary copy of Rutter (1899) in my possession, the middle initial "M" on the cover has been inked out. This middle initial does not appear inside the document or in the original *Bulletin of the United States Fish Commission* title page or table of contents. Rutter's correct middle name is Louis. As a youth, Rutter apparently went by his middle name for a period of time. Most of his friends and relatives called him "Cloud." The name is invariably misspelled as "Claude" or "Claudsley" by those who did not know him personally (e.g., see Anonymous, 1895, 1900b, 1902a). The given name of Cloudsley is of obscure origin; family tradition indicates that it was taken from a Victorian novel read by his mother (9 Feb. 1942 letter from Charles McClellan Stevans to Dora Holt; copy in CAS Archives). It has since been christened on a number of Rutter's descendants and relatives.

[5]Genealogical records of RRR.

Figure 2.—Rutter at the age of 4 (=1871) in Indiana. Original photo courtesy of Richard R. Rutter.

good natured) that would make him such an excellent student, researcher, and administrator (Fig. 2).

During his youth, Rutter's parents moved often—from Gibson County, Ind., to Wheaton, Ind.; to near Sumner, Ill.; then back to Fort Branch, Ind.; then to Bellmont, Ill.; to Washington, Kan.; to Burlington, Kan.; Atcheson, Kan.; Wynoose, Ill.; and finally back to Oakland City, Ind.—all during which time his father raised crops on rented farms and built houses. And it was under these varied conditions that Rutter first obtained his appreciation of nature and his love of fishes.

In later years, his sister Dora recalled that even as a small boy, Rutter had an inquisitive mind about the organisms around them. Often, when they came across an animal such as a freshly killed bird, her brother would wonder aloud what killed it and how it got there. As young farm children, Rutter and his sisters often went fishing (which they greatly enjoyed), and if conditions warranted, they would also hunt for flowers and try to catch and bring home other animals such as eastern box turtles, *Terrapene carolina*.

During their youth, they rarely got into serious trouble or fights, although Rutter once thought he had a close brush with death on 15 Dec. 1877 while playing in a straw pile on their farm in Washington, Kan. On that day, Rutter suddenly slid down from the straw pile and took off running and limping to the house, all the while screaming at the top of his lungs and holding his left shoulder. His mother heard him and came running out to see what was the matter. Rutter told her that "it was a snake and it had bit him all the way up his arm." She carefully looked under his coat, vest, his outside shirt, and his undershirt before she found the cause for concern—it was a mouse that he had accidentally squeezed to death when it crawled up his shirt sleeve!

A couple of years later while living on the Little Wabash River near Wynoose, Ill., Rutter and his sister Dora came upon a boat with a very large fish in it. While they stood around examining the situation, a man came by and said that the boat was his, but they could have the fish. They eagerly picked up the slippery fish and tried to carry it home, but it soon proved to be a bigger chore than they expected. Such was Rutter's first introduction to the paddlefish, *Polyodon spathula*, a species he would later study in depth while employed as an Assistant with the USFC.

Teenage Years and Early College Education, 1880–92

As a young boy, Rutter showed the traits of most adolescents his age—he was quite a prankster and loved to tease his friends and sisters. But as he got older, he blossomed into a bright, quick learner, especially adept at mathematics. As a young teenager, he thought that his future was to have a farm of his own. But during 1880, all it took was one summer of work on a local farm to change his mind. His daily regimen of rising at 0400 h, working all day, and finally getting to bed at 2030 h, left him exhausted, and he had trouble sleeping.

Even when he did manage to sleep, he was always dreaming about driving horses or doing other farm work. Only Sundays offered a respite from the daily drudgeries of farm work. Therefore, Rutter decided that an education was his best future and that he would only work with the cows and horses while on vacation. By age 16, he had graduated from Oakland City High School and was well known in the community for his woodcutting and carpentry skills. In fact, he once settled an argument amongst some local carpenters whether enough wood was present in the logs on site to construct a town building by figuring out all the timber cuts with his high school geometry and then getting them to build the structure. His calculations were correct and the men were impressed.

Rutter worked as a carpenter and on various farms in the Oakland City area until the fall of 1884 when he first began teaching in a public school in Oatsville, Ind., at the age of 17. During the summer of 1885, he worked with a bridge gang to help earn money for his college education. Given an adz and told to chop trees and other riparian vegetation, Rutter worked his unaccustomed student hands so hard that they became badly blistered. Soon after, his boss happened to notice that Rutter's blisters were bleeding on the adz. When asked why he did not say anything about his predicament, Rutter said that he did not want to. Such was his temperament of doing whatever it took to obtain the necessary resources to reach his goal of a good college education.

Later during the school term of 1885–86 (Fig. 3), he taught grade school for another year in local Indiana schools to make a living and then entered Indiana State Normal School (now Indiana State University) in Terre Haute. While there, he joined the local Baptist Church and soon became active in the local student community.[6] Rutter did his student teaching from

[6]Unpubl. records, ISU Archives. See also a transfer letter for Cloud L. Rutter from the First Baptist Church of Terre Haute (copy in CAS Archives).

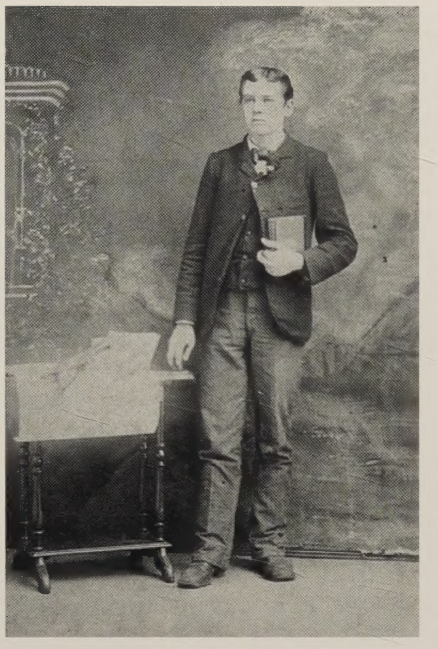

Figure 3.—Rutter upon his 18th birthday (=22 Feb. 1885) in Oakland City, Indiana. Original photo courtesy of Richard R. Rutter.

September 1887 to March 1888 in a public school west of town. One night while walking home from school along his regular route on the local railroad tracks, he quickly stepped aside to let the freight train pass. Unfortunately at that precise moment, something struck him sharply on the head. Luckily, his fur cap softened the blow, but he never learned what the object was that almost killed him. Eventually, he recovered without complications from the egg-sized bruise.[3]

Rutter was at Indiana State Normal School from September 1886 to June 1887 and from April 1888 to June 1890, where he took the standard course work in reading, composition, arithmetic, grammar, history, and Latin—but he apparently had time for only one quarter of zoology and two quarters of botany.[7] During this period, a fire completely destroyed the school and the students suffered many hardships (Lynch, 1946). However, Rutter stuck it out, ever inspired by class work and the excellent faculty. After graduation in June 1890 (Fig. 4), he taught school for a year in District #8 [Fairview] in Long Pine, Nebr., a location he had moved to in the summer of 1888 to be near his sisters and parents.[3]

In the fall of 1891, Rutter entered Doane College in Crete, Nebr., where he taught astronomy and pedagogy during his senior year while earning a B.S. degree in Pedagogy (Anonymous, 1891).[8] He apparently took classes in "English bible," "political science," "conics" [a form of mathematics], German, and French, where he maintained a B+ average.[9] Ever full of boundless energy, he even found time to work as a weather observer at the local Boswell Observatory for the U.S. Department of Agriculture in October 1891 (Swezey and Loveland, 1891).

By this time, Rutter was well known on the small campus as an enthusiast of the natural sciences, and he capped his education there by delivering a eulogy on Charles Darwin at the graduation ceremonies (Anonymous, 1892). Upon graduation from Doane College in June 1892 (and also receiving a teaching certificate from Indiana State Normal School at the same time), Rutter was hired by the newly formed Oakland City College in his old hometown to teach physical sciences and to raise endowment funds for the college at a wage of $50.00 per month (Shirley, 1985).

However, things did not work out as the "Panic of 1892–1893" dried up funds, and the tuition collected that first year was insufficient to pay the teachers' salaries. Thus during the fall of 1892, young Professor Rutter looked elsewhere for a livelihood and soon took up teaching at a public school in Johnstown, Nebr.[3] And it was here in Johnstown that he began his first association with the USFC.

[7]Unpubl. records, ISU Archives.

[8]Some of the books Rutter donated to the Doane College Library are still in their collection (unpubl. records, Doane Coll. Lib., Crete, Nebr.).

[9]Unpublished academic records for the Fall Term of 1891 and Winter Term of 1892, Doane Coll., Crete, Nebr.

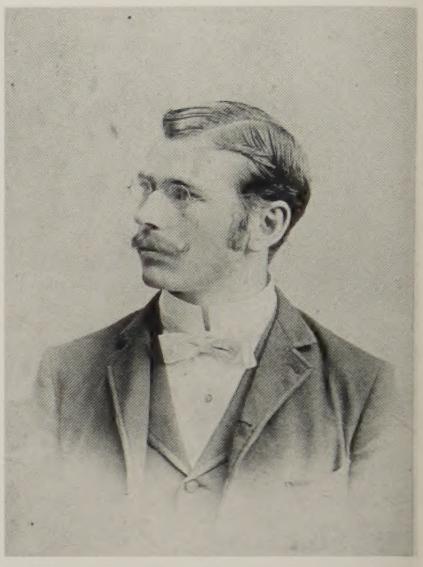

Figure 4.—Rutter upon his graduation from Indiana State Normal School in 1890. Original photo courtesy of Richard R. Rutter.

First Fisheries Work, 1893

As mentioned, Rutter had always been interested in fishes, and he first began his serious study of these organisms at Indiana State Normal School. This was due to Barton Warren Evermann becoming Professor of Biology and head of the Biological Department at the institution in 1886 (Chamberlain, 1904; Jennings, 1997a). Evermann was a keen student of zoology who first specialized in birds, but he soon switched to fishes at Indiana University [at Bloomington] (Hanna and Peers, 1944). By the early 1880's, this institution had become the center of ichthyological research in North America under its dynamic young president, David Starr Jordan (Hubbs, 1964).

Even while teaching at Indiana State Normal School, the indefatigable Evermann continued to work on his B.S. (1886), A.M. (1888), and Ph.D. (1891) degrees under Jordan's direction at Indiana University, and he quickly came to dominate the young students in the local Terre Haute Science Club (Jennings, 1997a). Ever willing to take the time to help a new student along

in the field of ichthyology as he himself had experienced only a few years earlier, Evermann began a long professional and personal friendship with the young Rutter which would last until the latter's death.

This early mentorship with Evermann would eventually pay dividends for Rutter when Evermann was hired on 25 June 1891 by the USFC and began fisheries surveys in the southern part of South Dakota and northeastern Nebraska during the summer of 1893 (Jennings, 1997a). Evermann retained Rutter as an Assistant to the USFC (at $60.00 a month plus necessary expenses) from 15 June 1893 to 29 Aug. 1893 (Rathbun, 1895, 1896a), thrusting him into the mainstream of government fisheries work. Liking the occupation, Rutter quickly made plans to continue his fisheries education in the new Leland Stanford Junior University in California, of which Jordan had agreed to become President on 23 Mar. 1891 (Jordan, 1922).

Rutter thus accompanied Professors Ulysses Orange Cox (of the State Normal School of Mankato, Minn.), Robert Greene Gillum (of the Indiana State Normal School), and Evermann in surveying the fishes and the need for planting food fishes in the newly created states of Nebraska, South Dakota, and Wyoming (Rathbun, 1895, 1896a; Evermann and Cox, 1896). They packed up their meager collecting outfit of one 4.575-m seine, one 7.625-m seine, one collecting bucket, and 60.56 L of alcohol (in two 15.14-L tanks and one 30.28-L tank) on an outfit of pack mules and headed out into the shortgrass prairie to sample promising streams.[10] A detailed itinerary of this trip is published in Evermann and Cox (1896).

Although Rutter assisted with the fish collecting for only 1 month, he nonetheless gained sufficient experience to spend another month with Charles Henry Gilbert, Oliver Peebles Jenkins, Wilbur Wilson Thoburn, and Evermann in a survey of the fishes (especially salmon resources) of the Columbia River Basin (Evermann and Cox, 1896; Rathbun, 1896a). A detailed itinerary of their trip is published in Gilbert and Evermann (1895).

Because Rutter proved to be such a capable field worker, Gilbert, Jenkins, and Thoburn (all professors at Stanford), soon put him to work with Evermann on a manuscript dealing with the fishes of the Colorado River. The resulting paper (Evermann and Rutter, 1895) is a useful compendium of what was known to that time about the taxonomy and ecology of the unique fish fauna of the Colorado River, an environment whose ichthyofauna has greatly changed over the past century owing to a series of major dams and the widespread introduction of dozens of exotic fish species (Minckley, 1973; Minckley and Deacon, 1991). Such thoroughness by Rutter in his first paper was to be a hallmark in many of his subsequent fisheries publications.

Figure 5.—Rutter's old room in 1901 at Stanford University which is jokingly referred to as "THE CELL." Original photo courtesy of Richard R. Rutter.

Stanford University Years

Undergraduate Education, 1893–95

Upon being released from his 1893 summer fisheries work in the Columbia River basin, Rutter packed up his belongings and took the train to Stanford University where he immediately began his class work in zoology (Fig. 5). Surviving class notebooks indicate his participation in a variety of subjects—he apparently enrolled in everything from comparative anatomy to botany and entomology.[11] Lectures were given by most of the Stanford zoology faculty—e.g., Frank Mace MacFarland, Jenkins, and Jordan—although it appears that much of the laboratory work was taught by seniors or graduate students.

Rutter quickly discovered that he fit in well with the pioneering class of undergraduate students at Stanford (as this small group of students was labeled (Jordan, 1922; Lyons, 1964)).

[10]Barton Warren Evermann files, box 125, "Fish Commission business-pre CAS" (CAS Archives). Rutter apparently spent a total of $748.51 on this expedition.

[11]Original class notebooks in the possession of RRR.

This may have been due to his maturity, but I believe that it was due to his cheerful personality, strong work ethic, and outstanding reputation for collecting natural history specimens. Because Rutter was a teetotaler, nonsmoker, and ardent Republican (or Mugwumps faction at that time), he aligned perfectly with Jordan, Gilbert, and other like-minded Stanford faculty.[12]

Assigned to work up the various fish collections which came to the university, he quickly became a trusted pupil and assistant to both Gilbert and Jordan (Jordan and Evermann, 1896; Jordan et al., 1930), the results of which are a number of papers on the ichthyology of China, the eastern Pacific, and the freshwater fishes of California and Arizona (Rutter, 1896a, b, 1897; Jordan and Rutter, 1897a), as well as singular descriptions of new species of fishes (Jordan and Rutter, 1897b, 1898). These publications are important because they provide the first documentation of several fish species in places where they are now rare or absent, as well as indicating the importance of certain food fishes during the 19th century.

Rutter was active in the Stanford Zoology Club where he was elected "Secretary of Batrachians [=Amphibians]" during the fall of 1893 and he also gave presentations on his natural history work (Anonymous, 1893a, 1894a). He even found enough spare time to compete on the university fencing team.[13] When he could, he accompanied faculty members and fellow students on a number of expeditions to remote parts of California (such as the Carmel River Expedition of July–August 1895) where he was able to collect many plant, fish, amphibian, and reptile specimens (Anonymous, 1893b; Rutter, 1896a, b; Böhlke, 1953).[14]

Although registered for summer school at the Hopkins Seaside Laboratory in 1894 (Anonymous, 1894b)—possibly because of an early interest in echinoderms (Cassino, 1896)—Rutter decided to take a break from his formal studies at Stanford University. He traveled east to work with Henry Frank Moore and B. L. Hardin of the USFC on a 6-month fisheries survey of Lake Erie and Lake St. Clair (Rathbun, 1896a, b).

While there, the group was largely engaged in collecting and studying the fishes and market fisheries in the region about Kelley Island, Ohio, and the Bass Islands, as well as obtaining information from the fishermen about the methodology, history, and conditions of the local fishery (Rathbun, 1896a). Several of the fishes they observed and collected in Lake Erie have since disappeared from that body of water—most notably the paddlefish of his youth (Trautman, 1957).[15]

Rutter was placed in charge of the group, under the direct supervision of Hugh McCormick Smith (Rathbun, 1896b). Although Rutter did not publish any papers based upon this work, he did attempt to have several short stories on his observations of local personalities published in *The Youth's Companion* (of Boston, Mass.). Unfortunately, none of his manuscripts were accepted for publication, and they were returned to Rutter shortly before his death. Since then, two of these manuscripts have been published as they provide century-old examples of how fisheries biologists utilized local resources in transporting their catch (Jennings, 1995) and the dangers of commercial fishing in Lake Erie (Jennings, 1996).

Graduation and Further Studies, 1895–1896

In January 1895, Rutter returned to Stanford University to complete his class work for the first of several degrees as a member of the "Pioneer Class."[16] His parents and sisters came out from Indiana and rented a small place in the nearby town of Mayfield[17] where they all lived together (Fig. 6). Rutter's mother apparently raised chickens (for eggs) and dairy cows (for milk and butter), while his father worked as a local carpenter and grew oats, wheat, and pumpkins on the plot of land surrounding the house.[18]

Although Rutter did not pay any tuition as a student (the official policy of Stanford University at that time), he nonetheless had to make enough money for his personal expenses and books. Thus Rutter worked as a candy maker (or salesman) in Mayfield to help make ends meet (Anonymous, 1895). He continued in this trade until he left for Alaska in May 1897 (Anonymous, 1896a, 1897). As for progress with his university studies, his old alma mater, Doane College, granted him an M.S. degree in June 1895, which was followed in quick succession by a B.A. degree in zoology on 8 Jan. 1896 and an A.M. degree in zoology on 27 May 1896 by Stanford University (Anonymous, 1932; Fig. 7).

Unfortunately, there is no record at Stanford to indicate if Rutter ever filed

[12]Comments regarding Rutter's abstinence from tobacco and alcohol and his political views are clearly stated in the letter cited in footnote 3 and Rutter's 1903 Alaska diary (see footnote 1). The views of Jordan, Gilbert, and other like-minded faculty are well stated in Jordan (1922), Brittan (1997), and Dunn (1997). Rutter was so strong in his views about alcohol that he once stated in a letter to his mother during the 1893 field season that he was treated to dinner by the Governor of Wyoming and that the Governor served beer. He commented that "...Ma, Professor [Robert Greene] Gillum drank because he liked it. Professor [Ulysses Orange] Cox drank because he was asked to, and I refused because I was taught to. No, not even the Governor of Wyoming can tempt me to drink." (see footnote 3).

[13]Rutter's fencing medal from an 1894 match with the University of California at Berkeley was apparently fashioned out of the reverse of a silver coin. It is a treasured family keepsake (RRR, pers. comm.).

[14]There are a total of 49 amphibian and 16 reptile specimens collected by Rutter present in the old LSJU Natural History Museum collections which are now housed with the herpetology collections of the Department of Herpetology, CAS (unpublished records, Department of Herpetology, CAS). Additionally, there are several detailed plant lists compiled by Rutter (originals in the possession of RRR).

[15]The fishes last collected specifically by Rutter in Lake Erie are the spotted gar, *Lepisosteus oculatus*, and the pugnose shiner, *Notropis anogenus,* (Trautman, 1957). All of Rutter's fish collections from this work are deposited in the USNM ichthyology collection.

[16]Fellow class members included Herbert Clark Hoover who would later become the 31st President of the United States (Lyons, 1964).

[17]The town of Mayfield was located about 1.5 km (.93 mi) southeast of Palo Alto at the turn of the century. It has since been incorporated by the City of Palo Alto.

[18]17[-24] Nov. 1896 letter from Hanna Rutter to Cloudsley Rutter (copy in CAS Archives).

Figure 6.—The Rutter family in front of their house at Mayfield, California, during 1895. Individuals (l–r) are: (sitting) George Austin Rutter, Avis Holt (Dora's daughter), Hanna Jane (Emmerson) Rutter; and (standing) Fanna Myrtle (Rutter) French, Cloudsley Louis Rutter, and Dora Elda (Rutter) Holt. Original photo courtesy of Richard R. Rutter.

a master's thesis for his A.M. degree requirements (Storey, 1957). It is possible that Rutter never wrote a master's thesis; he merely substituted one of his published papers for this requirement and his graduate committee members accepted the paper without indicating anything in the official record. This was not an isolated incident with graduate students in the first decade of the university's existence. For instance, classmate John Otterbein Snyder also received an A.M. degree without any indication of a master's thesis or substituted publication (Storey, 1957; Brittan and Jennings, 2008).

Perhaps Rutter's master's thesis is really Rutter (1896a, b), as this work was conducted at Hopkins Marine Station. It identifies Jordan and Gilbert as Rutter's teachers, and it was the first paper published after Rutter's May 1896 graduation date. Interestingly enough, this work is still important today because of the locality information and meristic data on the native freshwater fishes of California and southern Arizona, three of which are now listed under the Endangered Species Act by the United States Fish and Wildlife Service (Miller and Hubbs, 1969; Minckley, 1973; Williams et al., 1989).

Work With the Alaska Packers Association

Upon graduation with a master's degree from Stanford, Rutter was offered a job by the Alaska Packers Association to work for 1 year at their Karluk Fish Culture Station on Kodiak Island, which was located in the southern part of the then Territory of Alaska (Anonymous, 1896b). Because of the chance to work in a brand new fish culture facility and also to be able to collect natural history specimens in Alaska, Rutter jumped at the chance to go. Thus in July 1896, he boarded a sailing ship in San Francisco, Calif., taking 28 days to make the journey to Kodiak Island.[19]

Upon arrival, he soon found that the remoteness of the hatchery location and the scarcity of dependable labor made his job a real challenge. Part of the problem lay in the way that the fish culture station was conceived and where it was located. In 1896, nothing was known about the life history of sockeye salmon, *Oncorhynchus nerka*, and it was assumed that they could be planted as fry in brackish water without ill effect (Roppel, 1982). Thus, the hatchery was located right next to the estuary at Karluk so it could be near the supply base of the cannery operations (Moser, 1899).

James Albert Richardson (a former fish culture student of Livingston Stone at the USFC's Baird, Calif., hatchery) designed the layout, supervised construction, and was assigned superintendency of the hatchery by the Alaska Packers Association (Roppel, 1982). Based largely on Richardson's experiences at Baird and Sisson, Calif., with Chinook salmon, *O. tshawyts-*

[19]Alaska diary (see footnote 1).

Figure 7.—Rutter during December 1896 in Alaska soon after graduation from Stanford University. Original photo courtesy of Richard R. Rutter.

cha, this early state-of-the-art hatchery nonetheless did contain several novel innovations such as a boiler to heat the hatchery water artificially to hasten the egg incubation period (Roppel, 1982). Considered a model hatchery in 1896 (Fassett, 1902), it quickly became apparent in 4–5 years that it was unsuitable for effectively raising the millions of sockeye salmon fry that the canneries depended on (Roppel, 1982, 1986).[20]

But all the hatchery's inherent problems were unknown in 1896, and Rutter had little time to think about design flaws and site location problems. Ground breaking occurred on 28 May 1896 with the first fish spawn taken barely 3 months later (Roppel, 1982). Although there had been several short-lived attempts to culture sockeye and coho salmon, *O. kisutch*, at a number of sites on Kodiak Island in 1891 and 1892, all of these attempts failed because of disagreements over fishing rights, lack of suitable fish for spawning, or destruction of primitive hatchery facilities by the elements (Roppel, 1982).

Thus, everything Richardson and Rutter did with culturing sockeye salmon was new. They had no manuals or guides and could only correspond with colleagues via the inefficient mail service (it took at least 2 months to get a letter to the continental United States and the reply returned to Karluk).[21] Of everyone on the island, only Rutter had an extensive college education in fisheries. It was to be an interesting and very busy year for him in Alaska.

Originally during the 1890's, Kodiak Island's eight major salmon canneries wanted to rebuild the fish runs of their home streams by planting salmon fry from their own hatcheries. It was assumed that these efforts would eventually provide a sufficient supply of adult salmon for their cannery operations (Moser, 1899, 1902). Unfortunately, this was the era of expanding cannery operations, men, and gear (Roppel, 1986), as well as fights over fishing grounds (Jordan, 1922).

There was much exploration of new fishing grounds and various fish stocks. Quickly, this resulted in overexploitation of the local salmon fishery and a decline in the salmon pack (and profits), as well as a rise in tempers between rival canneries (Moser, 1899; Jordan, 1922). However, in 1896 the salmon canneries were still optimistic that if they were able to plant enough artificially cultured young fish in their company streams, then in due time a steady supply of adult fish would return to the canneries.

Thus the Alaska Packers Association built several hatcheries, but the work of taking fish spawn, raising fry, and liberating the subsequent fingerlings fell to the fish culturalists and the employees they hired. Most of the hatchery foremen were individuals with some practical fish culture experience elsewhere in the United States (especially California), but the laborers were essentially local residents and former fishermen. The first thing Rutter did was get the hatchery into shape so that they could obtain fertilized eggs and raise salmon fingerlings. Early on, he acquired a useful skill of determining which locals were trainable and thus trustworthy to hire for work in the hatchery.[22]

As in many coastal Alaska communities, alcoholism was a real problem with the workers (McKeown, 1948) and Rutter did his best to avoid those with a propensity for the bottle. However, his teetotaling did not endear him to most of the other hatchery foremen and cannery superintendents who considered turning down a drink to be the ultimate insult.[22]

The work at the hatchery became so demanding that Rutter had little time for collecting natural history specimens, much less writing papers. His old colleagues at Stanford did the best they could to encourage him to keep up his reputation as a formidable collector of specimens for Stanford University (Snyder even went to the trouble to send him mammal traps and give him specific instructions on how to "blow" bird eggs and collect nesting birds.[23])

However, all Rutter was evidently able to do was collect a few plants, mammals, and birds for Stanford (Seale, 1898; Kellogg, 1899; Grinnell, 1901; Friedmann, 1935; Hultén, 1940). One of the bird specimens was described as a new species of rosy finch, *Leucosticte kadiaka* (McGregor, 1901), which has since been synonymized under the gray-crowned rosy finch, *L. tephrocotis* (Gabrielson and Lincoln, 1959). As for fish collections, he eventually obtained a small series of tidepool fishes at Karluk in May 1897, at the very end of his tenure at the hatchery (Rutter, 1899).

[20]See also Wisner, J. N. 1903. "Alaska Report, 1903". Hatchery Inspection Report, 1903–1910, General Records, Division of Alaska Fisheries, RG-22, National Archives.

[21]The first manual of fish culture dealing with Pacific salmon was published in 1898 (Brice, 1898) and quickly revised in 1900 (Brice, 1900). However, these manuals were almost entirely based on experiences with Chinook salmon and rainbow trout, *Oncorhynchus mykiss*, at the Baird Hatchery, something that Richardson was already familiar with. They contained nothing on sockeye salmon culture.

[22]Rutter's 1903 Alaska diary (see footnote 1).

[23]12 Mar. 1897 letter from Snyder to Rutter (copy in CAS Archives). Letters were also received from fellow LSJU classmates James Francis "Frank" Abbott, Arthur White Greeley, and George Clinton Price.

U.S. Fish Commission Work

California Salmon Studies, 1896–1898

With the completion of his contract with the Alaska Packers Association and his return from Karluk in June 1897, Rutter was once again hired as an Assistant with the USFC (Anonymous, 1900a). However, instead of working on the fishes of the Midwest or Great Lakes, he was assigned to work with Norman Bishop Scofield of the California Fish Commission on a project dealing with the life history and status of Chinook salmon resources of the Central Valley of California. This work was to eventually become Rutter's most important contribution to fisheries science.

During the late 1880's and early 1890's, it was readily apparent to fishermen and the fishing industry that the Chinook salmon resources of California's Sacramento-San Joaquin River system had been badly overfished. Beginning with the first salmon cannery on the Sacramento River near Sacramento in late 1864, this lucrative fishery quickly expanded to 19 canneries by 1884 and then went into such a steep decline that only one-eighth the size of the catch of the peak run of fish in 1882 was realized by 1890 (McEvoy, 1986; Lufkin, 1991).

Besides extensive overfishing, the remaining salmon stocks also had to deal with the destructive effects of large hydraulic gold mining operations on major spawning streams, stream diversions for irrigation, and pollution such as sawdust and raw sewage being dumped into rivers throughout the Sacramento-San Joaquin Basin (McEvoy, 1986). Although there had been several calls by resource users to address this situation, the best that the California State Board of Fish Commissioners (CSBFC) could do besides urging protective laws (which were not effectively enforced until adequate funding for wardens was obtained in 1907 [Welch, 1930]), was to attempt to have hatcheries built that could artificially raise fry from fertilized eggs obtained from wild salmon and subsequently release these salmon fry (or fingerlings) into the Sacramento River drainage. It was to be the beginning of a long series of "studies" and "mitigation projects," a legacy of the Progressive Era that continues unabated today (Black, 1995, 2003).

However, the CSBFC was also hampered by the rudimentary knowledge of the biology of Chinook salmon in the Sacramento River or anywhere else for that matter. Even the most basic information—such as the food habits of young salmon, the length of time spent in the ocean, and the death of all adults after spawning—was unknown at that time. Thus to the credit of the CSBFC, the California State Legislature, the USFC, and local Congressmen, necessary legislation and money was assembled during the summer of 1896 to start a cooperative federal and state study of the life history of Chinook salmon. Apparently Norman Scofield was responsible for the overall investigation, assisted by USFC Fishery Expert, Alvin Burton Alexander beginning in February 1897 (Smith, 1898; Scofield, 1900a). The studies were closely monitored (on almost a daily basis) by the Executive Officer of the California Fish Commission [John Pease Babcock] who, from its inception, took an active interest in the project.

The study started in December 1896, with 855,000 eyed Chinook salmon eggs being shipped from the government's Battle Creek Fish Hatchery in Tehama County to the state's Bear Valley Fish Hatchery in Marin County (Scofield, 1900a). These eggs were hatched in early February 1897 and then held for several weeks until they reached the swim-up fry stage (Scofield, 1900a). During the second week of March 1897, the remaining 700,000 swim-up fry were released into Paper Mill Creek [=Lagunitas Creek] and its major tributaries, a small coastal stream in Tomales Bay just north of San Francisco (Smith, 1900).

The short-term goal was to make extensive observations of the movements, enemies, growth, and food habits of juvenile salmon. The long-term objective of the study however, was to determine if adult salmon returned to their natal streams to spawn by planting young Chinook salmon into a drainage known to be devoid of the species (Smith, 1898). Alexander began the observations and continued until the middle of May. After a break of 3 weeks, Scofield continued the field work until the fish had migrated downstream in July (Scofield, 1900a). They had about 4 months of data when Rutter was hired to replace Alexander and thus allow the USFC to take a larger role in the studies (both conceptually and financially).

Rutter went to the Battle Creek Station [=Fish Hatchery] in August 1897, where he apparently helped take a record number of fall-run Sacramento River salmon coming up the stream (Ravenel, 1899). With their efficient fish weir and nets (Fig. 8), they took almost every fish coming up Battle Creek (Scofield, 1900b) which resulted in 8,784 fish being spawned and 48,527,000 eggs being taken (Ravenel, 1899). Of this amount, 24,000,000 eyed eggs were turned over to the California Fish Commission (to be hatched on the Sacramento River and Eel River); 4,000,000 eyed eggs were sent to the USFC's McCloud River Fish Hatchery at Baird, Calif.; 6,000,000 eyed eggs were sent back east; 2,000,000 eyed eggs were transferred to Bear Valley Fish Hatchery; and 3,000,000 eyed eggs were sent to the USFC's Clackamas Fish Hatchery near Portland, Oreg. (Ravenel, 1899). Only 6,000,000 eyed eggs were reserved for Battle Creek. Of this amount, 5,885,500 fry resulted which were eventually planted back into Battle Creek in February 1898 (Ravenel, 1899). Rutter was apparently kept very busy catching and spawning eggs between 20 October and 10 December 1897.

In mid-December 1897, through February 1898, Rutter worked at Olema, Bear Valley, Calif. (Ravenel, 1899) where he assisted Scofield with raising the batch of transplanted Battle Creek salmon eggs at the Bear Valley Fish Hatchery. Rutter and Scofield

Figure 8.—Catching adult Chinook salmon in Battle Creek, California, during 1901 for the nearby federal fish hatchery. Original photo courtesy of Richard R. Rutter.

also seined for juvenile salmon and steelhead trout, *O. mykiss*, in the lower reaches of Paper Mill Creek (Scofield, 1900b). They apparently caught one precocious male salmon in Bear Valley Creek, which was quite noteworthy at the time because they knew the precise age of the fish (exactly 12 months) and could thus show that precocious males found in natural salmon runs are fish that matured at a younger age rather than just being stunted individuals (Scofield, 1900a).

As for their salmon culture activities, they ended up planting 2,000,000 sack fry in Paper Mill Creek and its tributaries during the last week of February 1898, about 3 weeks earlier than the year before (Scofield, 1900a). Because of the limited hatchery space and lack of funds, all fry were planted before their yolk sacs were absorbed, an action which probably resulted in a substantial loss of young fish.

With the conclusion of salmon work in February 1898, Rutter was assigned to work in southern California. During March and April 1898, he took data on the commercial fisheries of San Diego (Townsend, 1899). Markets had recently been found in Kansas, Texas, Missouri, and other states west of the Mississippi River for fresh ocean fish (such as California barracuda, *Sphyraena argentea;* California halibut, *Paralichthys californicus;* and rockfish, *Sebastes* spp.); as well as spiny lobsters, *Panulirus interruptus*, from the southern California ports of San Pedro and San Diego. Rutter attempted to estimate of how many kilograms of each commercial fish species were handled by the San Diego dealers in 1897 as well as how the fishermen obtained their catch (Townsend, 1899).

California Salmon Surveys, 1898

After he completed his fisheries work in San Diego, Rutter was again assigned to work on the Sacramento salmon study with Scofield and also with Frederic Morton Chamberlain (Fig. 9) of the USFC (Smith, 1899). Chamberlain and Rutter were well acquainted with each other from their days as Evermann students at Indiana State Normal School (Jennings, 1987). To make a general survey of the Sacramento River and its resources, Rutter went by steamer during late April–early May from San Francisco to Redding, a distance of about 547 km (340 mi) (Smith, 1899). Where the steamer stopped along the river (Sacramento, Red Bluff, Tehama, Battle Creek, and Redding), Rutter briefly seined for salmon and found them to be abundant, except at Sacramento (Scofield, 1900b).

In mid-May, Rutter accompanied Scofield on a careful reconnaissance of the Sacramento River from the headwaters near Sisson, downstream to Sacramento. The last 10 days of

Figure 9.—Frederic Morton Chamberlain about 1900 during a lighter moment in California. Original photo courtesy of Richard R. Rutter.

the trip (May 20–30) were conducted by rowing downstream in a skiff from Red Bluff to Sacramento (Fig. 10). Periodically, they stopped and seined the river at every available place to learn the abundance, size, and movements of young salmon (Smith, 1899; Scofield, 1900b).

By the beginning of June 1898, Rutter was back in San Francisco. There he wrote his mother that he had just received a letter from Dr. Smith (at that time the head of the USFC's Division of Scientific Inquiry) which stated "I think you will be retained on this work until the beginning of salmon hatching at Battle Creek, when I should like to have you return to that place and continue the observations and experiments begun last fall." Rutter was very pleased with the prospect of resuming his salmon work. He would probably be called to visit the USFC in Washington, D.C., to work on his report and thus he could visit "home" in Oakland City, Ind., for a few days or weeks.

However, not all his research activities went smoothly as Rutter subsequently reported that "...yesterday morning at Sacramento, Mr. C[hamberlain] and I wanted to get a boat to go to a fishing place about five miles below Sacramento. The boat keeper, a woman, said the law, under which boat licenses were held, forbid boats being taken below the railroad bridge. We wanted to go a short distance below to get our seine, and then go to a place a mile north, but that wouldn't do. As for rowing to the place five miles below, she said we would never get back. She declared we couldn't go a mile in three hours against the current and wind. Chamberlain thought we knew as much about what we could do as she did. We hired a dray [=horse drawn cart without sides] to take our seine to the boat, and started to the place a mile above. We wore ourselves out, and didn't make a quarter of a mile!"[24]

Throughout most the rest of June 1898, Rutter spent his time at Stanford University where he worked up his 1897 Karluk, Alaska, fish collections. This work resulted in the naming of the new genus "*Sigmistes*" (Rutter, 1898b) as well as two new species of fishes: *S. caulias* and *Porocottus bradfordi* (Rutter, 1898a, c, 1899). During this time he waited for further instructions from USFC headquarters in Washington, D.C.[25]

Figure 10—Rutter with fish sampling gear in a skiff during 1901 on the Sacramento River, California. Original photo courtesy of Richard R. Rutter.

Washington State Salmon Surveys, 1898

Early in July 1898, Rutter was again ordered to make a trip down the Sacramento River, but he was unable to locate any juvenile salmon below Battle Creek (Scofield, 1900b). The juvenile fish had apparently already migrated downstream to the delta for the season. Thus in mid-July 1898, Rutter was assigned by the USFC to begin a systematic coastal survey of the salmon streams of Washington State. At times he was assisted by local residents Chauncy F. Foote and Elmer Raymond Brady (Smith, 1899; Evermann and Latimer, 1910).

The survey began about 25 July immediately north of the Columbia River and concluded on 1 October, by which time all major streams on the south side of the Strait of Juan de Fuca had been examined. Although they did not find any new species of fishes during their 2-month survey (Evermann and Latimer, 1910), Rutter did note that most of the streams were inhabited by Chinook and coho salmon. Even chum salmon, *O. keta*, were found to be present throughout the region, ascending even the smallest streams to spawn. They also discovered an interesting population of sockeye salmon and its freshwater form, the kokanee, *O. nerka kennerlyi*, in the Quinault River system. Altogether the expedition turned out to be successful as Rutter managed to make large collections of fishes and other aquatic life.

However, when the specimens were sent back east to the Smithsonian Institution, the biggest surprise in the collection turned out to be an amphibian rather than a fish. It seems that Rutter unknowingly captured the first specimen of the tailed frog, *Ascaphus truei*, in his collecting net on 19 Aug. 1897 at Humptulips, Grays Harbor County, Wash. (Burt and Myers, 1942). Because this frog is one of the most primitive anurans known (Zug, 1993), its discovery in North America turned out to be the last great herpetological event of the 19th century (Stejneger, 1899).

Northeastern California Fish Surveys, 1898

In September 1898, Rutter returned to California from Washington State by train and stopped in at several points along the way to collect fishes in the upper Pit River system, Goose Lake, and the upper Lahontan sys-

[24]3 June 1898 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[25]27 June 1898 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

tem with Chamberlain (Smith, 1900). Some of the most exciting finds on this trip were the discovery of six new species of fishes including suckers, *Catostomus* spp., and sculpins, *Cottus* spp., in the upper Pit River and a sucker and tule chub, *Gila bicolor*, in Eagle Lake (Rutter, 1904c, 1908). Rutter even suggested naming the new sculpin [=*Cottus*] from the Fall River after Evermann "...if you aren't a *Cottus* already!"[26]

While at Redding, Calif., Rutter wrote to his mother in Indiana and discussed the efforts of his father who was currently building a house in Mayfield, Calif., where they could all live together comfortably (that is, Rutter's parents and two sisters as well as himself) for only about $12.00 a month—which was quite an achievement at that time.[27] To make this effort a reality, Rutter often sent home large amounts of money from his paycheck each month, an amount usually greater than $50.00, while his father provided the sweat and labor of construction. From 1897 to 1898, Rutter's father worked nonstop at building the house which turned out to be a harder job than they expected.[27] It was apparently completed just before Christmas 1898, but there is no evidence that any of the Rutter family members ever lived there.

California Salmon Studies, 1898–1899

From Redding, Rutter traveled north to Baird where he made a series of experiments on the hatching of salmon eggs and the embryology of young salmon (Anonymous, 1898; Smith, 1901). He then continued on to the upper Sacramento River at Sims, where he continued monthly observations on the numbers and growth of young salmon, collected fishes, and explored local streams (Smith, 1900). He apparently also spent a couple of weeks in the headwaters of Mill Creek and the Feather River collecting fishes with Chamberlain, before traveling to Battle Creek. There he spent October–November 1898, studying the life history of young salmon in the creek with the use of a downstream migrant trap (Smith, 1900). It was during this period that he obtained his nickname of "Professor" at the Baird Hatchery because the other hatchery assistants thought of him as a "college boy" (Rutter, 1902b).

By this time, Rutter had a fairly complete picture of the life history and ecology of spawning salmon and their young in the Sacramento River drainage. Although it took a number of months for him to work this material up for publication, his results and conclusions were quickly passed on to his superiors where they were published in an abridged form (Smith, 1900). These conclusions were important because they set much of the basis for California salmon management and research during the 20th century (Clark, 1929; McEvoy, 1986; Black, 1995, 2003).

The most far reaching of Rutter's conclusions were: 1) increase the number of restrictions on fish harvest in freshwater habitats (harvest restrictions in saltwater habitats were to come later), 2) rely upon hatcheries as the primary method of increasing salmon runs, and 3) continue scientific studies to find out more about the ecology of salmon and thus justify future "scientifically-based" management decisions (Black, 1995).

By the end of 1898, Rutter also had assembled quite a photographic record of his expeditions. He used a small Kodak[28] camera of the era as well as a larger reflex camera for taking his pictures, and he apparently also developed most of his own photographs in a makeshift laboratory. Some of his best photographs of live fishes were taken with the aid of a specially constructed, portable, glass aquarium that Rutter designed and built. Many of these photos provide an important historical record of conditions in California at the turn of the century, as well as a chronicle of the life cycle and use of salmon by local residents (Rutter, 1902a, d, 1904d). He sent a number of these pictures back east to his mother and told her to take good care of them as he thought he might want to use them in the future for an illustrated lecture on California.[27]

Upon completing his experiments on the hatching of salmon eggs at Baird, Rutter visited Stanford University on 7 Dec. 1898, while in route from the Battle Creek Hatchery to Monterey (Anonymous, 1898). There he talked with colleagues and visited old friends before moving on to the University's Hopkins Marine Laboratory at Pacific Grove. At the lab he conducted an exhaustive study of the effects of various densities of salt water on the hatching and development of salmon eggs (Anonymous, 1898). What motivated this study was to determine if salmon fry could be planted near the ocean so they would not have to be exposed to the large number of predators during their long journey down the Sacramento River to San Francisco Bay (Smith, 1900). The experiments (utilizing 50,000 eggs) were conducted from 12 Dec. 1898–15 Feb. 1899 and showed that developing embryos and young salmon could not live in undiluted sea water (Smith, 1900; Rutter, 1904b).

After the Pacific Grove experiments, Rutter traveled to Walnut Grove where he worked on his salmon report. At Georgianna Slough he and Scofield tended a downstream migrant salmon trap along the Sacramento River through May of 1899 (Smith, 1900), and while working together, they decided to combine their reports on the Sacramento salmon investigations to be as comprehensive as possible for those interested in their work. Rutter commented to his old mentor Evermann that "I think we are going to have something pretty good" with regards to this report.[26] However, little did he realize just how important this report (Rutter, 1904b) was to become

[26]25 June 1899 letter from Rutter to Evermann (U.S. Fisheries-Cloudsley Rutter box, Barton Warren Evermann files, CAS Archives). Rutter apparently had to settle on another species name for the rough sculpin, *Cottus asperrimus* Rutter, 1908, because Evermann already had a sculpin named after him.

[27]15 Sept. 1898 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[28]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

for salmon biologists during the rest of the century.

From Walnut Grove, Rutter then moved to Stanford University where he worked up the fishes collected during the previous summer's work. Several new species were found in these collections, including two new suckers and one new mountain sucker, *Pantosteus lahonton* [=*Catostomus platyrhynchus*], from Honey Lake and the Feather River Basin (Rutter, 1904c, 1908). Rutter also noted that tule perch, *Hysterocarpus traskii*, were found in the Pit River at Canby, which was only 29 km (18 mi) downstream from Alturas.

During June and July, he found himself so busy he offered to pay all his living expenses at Stanford University in exchange for completing all the work assigned to him by the USFC for that year. However, this "suggestion" only resulted in the USFC agreeing to have Rutter pay for all his own living expenses. He was still obliged to prepare for more field work as quickly as possible. Such "rewards" made Rutter decide to withhold further complaints to headquarters.[26]

In early August, Rutter became sick from a very bad sore throat, which was apparently the result of a long standing catarrh which he had put off treating for years. Since he was normally the tallest person in the group during field expeditions[29], he often had to wade into the water to set the deep end of fish collecting nets or dive underwater to dislodge nets snagged on submerged logs or rocks. This resulted in him being exposed to the elements more than others, and he thus had to put up with more than the usual share of colds, chills, and fevers.

Rutter's sore throat this time was apparently so bad that he wanted to see a physician about it. He did not have much confidence in the local Palo Alto doctors, but he also did not want to pay the money to go to San Francisco to get treated. After several days of lying around in misery, he eventually went to San Francisco to obtain treatment and it cost over $6.00. He remarked to his mother "My how the doctors do charge out here. If I weren't so old, I'd study medicine. I suspect that they charge me more because they think I am a government official and must have lots of money."[30]

While trying to recover, Rutter awaited orders from Washington, D.C. When they failed to arrive, he took the time to visit a young lady across the bay in the town of Alameda. He originally met her the previous year when he was at the California State Fish Hatchery at Sisson and recalled that she "didn't drink beer." He had supper with her and her married sister and was a big hit with the latter's little 2-year old daughter.[30]

California Fish Surveys, 1899

Rutter did not have a clue as to what he was going to do later that year and continued to wait for orders from the USFC which were supposed to appear any day. Finally in mid-August, the USFC's orders were conveyed by Hugh McCormick Smith, and Rutter left Stanford on 20 August for an ichthyological survey of the streams emptying from the east into the Sacramento and San Joaquin valleys (Anonymous, 1899; Smith, 1901). He was accompanied by a fellow Stanford University zoology graduate, William Sackston Atkinson, and they spent the next 7 weeks assembling large collections of fishes (Anonymous, 1899; Rutter, 1908). Although snow kept them out of the mountains in the southern part of California, they were able to collect specimens most everywhere else within the Central Valley. However, the heat of the valley and the rigors of the expedition were apparently too much for Atkinson, as Rutter mentioned "he is a very agreeable fellow, but not strong enough for the work."[31]

Upon their return to Stanford University in mid-November, Rutter worked up that summer's fish collections and wrote up his report on the fishes of the Sacramento-San Joaquin Basin. He was disappointed with the meager number of new species found during the most recent expedition, especially when compared with the surveys of the previous year, but he looked forward to taking a leave of absence in December to visit his parents in Indiana.[31]

At the time, Rutter believed that "it seems probable that I am to take up a sturgeon [=*Acipenser transmontanus*] investigation next year."[31] Instead, he was assigned to complete identifications of all of his fish collections at Stanford University (Anonymous, 1900a) and finish several major portions of his salmon report which covered the past 4 years of work.

By now, he had traveled over 3,379 km (2,100 mi) by land and water exploring the Sacramento-San Joaquin River drainage and its many tributaries, making minute observations on the life and habits of young salmon (Anonymous, 1900b). He also helped establish a new federal salmon egg collecting station and fish hatchery at the mouth of Mill Creek (Smith, 1901; Fig. 11). At the end of January 1900, his comprehensive salmon report was completed and submitted to Washington, D.C., where it was favorably received by his superiors (Smith, 1901).

California Salmon Studies, 1900–01

During the winter of 1900–01, Rutter and Chamberlain often had dinner together where they stayed up late at night talking about many fisheries subjects. They also went shopping together in San Francisco where they apparently investigated oil stocks among other things. On 18 Jan. 1901, they invested in several dollars worth of art at Doxey's Auction where Rutter purchased a fish picture for his office.[32]

[29]Based on examinations of Rutter standing in photographs (where he stands next to people of known heights), I estimate that he was about 1.85 m (6 ft) tall.

[30]2–8 Aug. 1899 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[31]22 Oct. 1899 letter from Rutter to Evermann (Barton Warren Evermann files, box 130, "U.S. Fisheries-Cloudsley Rutter," CAS Archives).

[32]Unpublished diaries of Frederic Morton Chamberlain, 1900; 1901–02 (originals in SI Archives [Record Unit 7258, Frederick [sic.] M. Chamberlain Papers, 1899–1909]).

Figure 11.—Mill Creek Hatchery in 1901. Original photo courtesy of Richard R. Rutter.

Figure 12.—Branded Chinook salmon (note the number 27 on the operculum) during the summer of 1901 at Black Diamond on the Sacramento River, California. Original photo courtesy of Richard R. Rutter.

During this time, a distant relative stopped by in San Francisco (at CAS) and decided to look up the young government fisheries biologist. After spending a only a few days with Rutter while touring around San Francisco, he became so impressed with his cousin's salmon work and good sense of humor that he decided to write a few lines about him in his book about traveling across the United States. The relative later commented: "Call at the government fishery department for Cloud Rutter, he said at parting. He hatches canned salmon for the government. Each one lays a million eggs and the United States employs him to find out how to get them all into the can" (Stevans, 1900).

Besides the above, it was during the spring semester of 1900 at Stanford University that Rutter made a great impression upon a newly arrived master's student of Charles Henry Gilbert. According to the recollection of Joseph Grinnell some 25 years later, Rutter clearly pointed out some of young Grinnell's personal handicaps while they and other faculty and students worked on the tables in the zoology laboratory (Linsdale, 1942). Fortunately for future zoology students at the University of California, Grinnell was able to correct these handicaps and go on to an outstanding teaching, research, and editorial career as the first Director of the Museum of Vertebrate Zoology at the university (Linsdale, 1942).

By the spring of 1901, Rutter was busily involved with sorting and identifying fishes at CAS, as well as writing reports and preparing for another season of field work. Much of the report writing dealt with studies of the circulatory system of salmon, as well as changes in the alimentary tract of salmon during migration (Smith, 1902). Additionally, Rutter conducted a number of marking experiments with juvenile and adult salmon and planned to release around 10,000 finclipped juvenile salmon later in the fall (Smith, 1902). In the meantime, he was able to brand 150 adult salmon at Black Diamond (Fig. 12); the subsequent recovery of three of these fish upstream provided information on the rate of migration up the Sacramento River (Rutter, 1904b; Smith, 1904).

During this period, Rutter also mentioned seeing President McKinley on 18 May 1901 during the launching of the Battleship U.S.S. *Ohio* in San Francisco Bay (Anonymous, 1901a).[33] Apparently there were over 250,000 people at the event and the parade afterwards through downtown San Francisco (Anonymous, 1901a). Although Rutter had a choice seat to observe the parade from his office window at CAS, the event apparently ended up being a pretty hectic day for him as his office was "full of women"—the result of friends and coworkers allowing their relatives to use Rutter's office.[33]

Sea Lion Studies, 1901

In July–August 1901, Rutter was placed in charge of a joint federal and state study to determine the kinds of food eaten by "sea lions" (*Eumetopias jubata* and *Zalophus californianus*). During the 1890's, a number of fishermen along the Pacific Coast had complained that their salmon catches were declining due to depredations by sea lions (Smith, 1904). The fishermen were especially adamant that these marine mammals were very destructive to their nets and other fishing gear.

Eventually, the Oregon legislature passed a bounty of $2.50 for each sea lion killed within the freshwaters of the state [=Columbia River] or within 4.83 marine km of the Oregon shore (Smith, 1904). Soon after, the CSBFC, under pressure from commercial fishermen, began killing sea lions in 1899 and asked for permission to kill these animals on federal lands (mainly in the seal rookeries on offshore islands controlled by the Lighthouse Board).

[33]19 May 1901 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

Their request was denied by the Treasury Department because of the lack of evidence showing the destructive habits of sea lions on commercial fisheries (Smith, 1904).

Such actions and comments resulted in a controversy among scientists as to whether sea lions live mainly on fish or other marine creatures (Anonymous, 1901b). Eventually, a 6 June 1901 request by the CSBFC for a study of the food habits of sea lions along the California coast resulted in Rutter and his team being assigned to collect a series of seal stomachs and examine what they contained. They began their studies on 10 July 1901 and worked the area from San Francisco to Santa Cruz and all the islands south of Point Conception. They visited every locality known to host sea lions and, after a good deal of difficulty, ended up shooting 66 specimens (Rutter et al., 1904).

Rutter (representing the USFC), Robert Evans Snodgrass (representing the California Fish Commission), and Edwin Chapin Starks (representing CAS) spent almost 2 months along the California coast investigating food items eaten by sea lions. Snodgrass and Starks returned to Stanford University on 5 Sept. 1901 (Anonymous, 1901b), while Rutter continued traveling north to northern California, Oregon, and Washington, where he visited sea lion rookeries and observed commercial fishermen at Point Arena, the mouth of the Columbia River, Tillamook, Oreg., Puget Sound, Wash., and the Straits of Juan de Fuca (Smith, 1904). Rutter eventually returned to Stanford University a few weeks after Snodgrass and Starks.

Although only two notes appeared as a result of this work (Rutter, 1903e; Rutter et al., 1904), they both indicated that Pacific salmon were a negligible part of the diet of sea lions, except perhaps at the mouth of the Columbia River where the water was shallow and salmon were abundant.[34]

Rutter (1903e) and Rutter et al. (1904) also provided some of the first information on the actual number of sea lions counted at Año Nuevo and Purisima Point along the central California coast.

California Salmon Studies, 1901–1902

From September to December 1901, Rutter was busily engaged in a study of the embryology of Chinook salmon at Battle Creek Hatchery (Fig. 13), as well as conducting surveys for salmon spawning beds in the Sacramento River (Smith, 1904). Some of this work was prompted by previous studies on the harmful effects of copper sulfate and sulfuric acid on fry and fingerlings of salmon held under laboratory conditions.[35] These chemicals were presumed to be the cause of major fish kills in the upper Sacramento River in 1899 and 1900 below the large copper mines and smelter complex at Keswick (Smith, 1902).[36]

After spending much of January–May 1902 working on a number of reports (Smith, 1904) and moving his office[37], Rutter finally finished the last sections of his long anticipated salmon report which was eventually released on 30 Mar. 1903 (Rutter, 1904b). In a rare confession to a friend, Rutter confided that "...I think Gilbert wants me to use it [the salmon report] as a Ph.D. thesis, but I don't know about that. I am not very anxious to get a degree from him. I have not said anything to him about it and shall not for some time yet."[38] As noted by others (Dunn, 1997), Gilbert could be a very exacting taskmaster and Rutter apparently did not want to endure the added stress of obtaining a Ph.D. degree under his supervision.

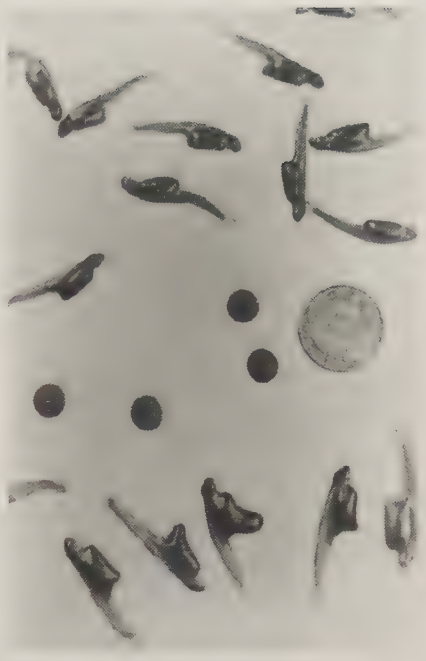

Figure 13.—Photograph of developing Chinook salmon embryos in 1901. The coinage is the reverse of a Barber dime. Original photo courtesy of Richard R. Rutter.

Rutter's (1904b) salmon report was a milestone at the time because it was the first treatise on the life history of a single fish species in western North America—and it soon became recognized as a classic in the field of salmon ecology (Chamberlain, 1907). The culmination of years of painstaking observation and experimentation, it finally provided enough factual information on the ecology of Chinook salmon in the Sacramento River to provide the basis from which sound fisheries management might eventually be derived.

Although almost all of Rutter's comments about the ecology of salmon are accurate, several of his most significant conclusions involve aspects of fish hatcheries, then perceived as a technological solution for the decline of commercial salmon stocks that the USFC vigorously supported (McEvoy, 1986; Black, 1995; Weber, 2002).

[34]Sea lions are presently considered to be major consumers of Pacific salmon in some areas now that their population numbers have grown to record levels along California, Oregon, and Washington coasts, while salmon populations in the same area have reached all time lows (Fiscus, 1980).

[35]Chamberlain diary, 1900 (see footnote 32).

[36]Acid mine drainage from nearby Iron Mountain is still a major problem for Chinook salmon and other resident fishes in the upper Sacramento River below Keswick Dam.

[37]Chamberlain diary, 1902 (see footnote 32).

[38]Letter fragment [Barton Warren Evermann files, box 130, "U.S. Fisheries-Cloudsley Rutter", CAS Archives].

Figure 14.—The Sacramento River near Red Bluff, California, during 1901. Original photo courtesy of Richard R. Rutter.

Figure 15.—Rutter at the oars of his skiff in the rapids of Iron Canyon on the Sacramento River, California during 1901. Original photo courtesy of Richard R. Rutter.

Although a number of Rutter's conclusions were used to manage salmon resources in the Central Valley of California (Clark, 1929), subsequent calamitous human interference with the aquatic environment of the Sacramento-San Joaquin River system has resulted in the eventual loss of most of the salmon stocks Rutter studied—despite the suggestions and repeated warnings of many fisheries biologists over the years (McEvoy, 1986; Lufkin, 1991; Fisher, 1994; Moyle, 2002).

Upon submission of his completed salmon report to headquarters, Rutter began working on a series of popular articles for the general public about the life of Pacific salmon (Rutter, 1902b, c, d, 1903a, 1904d). These articles (often illustrated by Rutter's own hand-drawn figures[39] and photographs), were important in educating the lay public about the economic importance and fascinating life history of the various species of Pacific Coast salmon, especially since newspapers and popular magazines were the only way to disseminate this kind of information in the days before radio and television.

Besides salmon, Rutter also wrote about threespine sticklebacks, *Gasterosteus aculeatus*, (Rutter, 1902e), rainbow trout (Rutter, 1903b), and other native California freshwater fishes (Rutter, 1903c), to interest the public in appreciating fishes (and their culture) and to suggest ways of keeping some of the smaller species in home aquaria. Additionally, Rutter wrote several condensed articles about his Chinook salmon studies for the CSBFC and its workers (Rutter, 1902a, 1904a, e, 1907).

Of all of Rutter's popular publications, two deserve special mention because of their significance in later years. Rutter (1902d) describes journeying (with Chamberlain) down the Sacramento River at the turn of the century when the river was essentially an undammed watercourse with thick riparian forests along its banks (Fig. 14). Travel was conducted in wooden 5-m skiffs powered by 2.7-m oars (Fig. 15). The most dangerous aspect of this kind of boating was not the rapids or whirlpools, but rather the numerous cables strung across the river (1–2 m above the water surface) to catch salmon and other fishes (Rutter, 1902d, 1903a).

It seemed that around the turn of the 20th century, the residents of the Sacramento River often attached spoonhooks to these cables by means of iron rings, which in turn, had a small line connected to a flag or bell on shore (Rutter, 1903a). When the bell rang, it indicated that a fish was hooked on the line. Only the physical labor of retrieving the "bell line" by hand was thus required to bring the hooked fish to shore (Rutter, 1902d).

Rutter's detailed comments and accompanying river photographs are important sources of historical information on what the Sacramento River was like at the turn of the 20th century. It also revealed the conditions under which Rutter and his coworkers

[39]Many of the original drawings used in publications such as Rutter (1902b, c, d; 1903c) are still in the possession of RRR.

toiled while conducting their fisheries studies. Rutter was apparently paid for submitting this article [Rutter, 1902d] to *Sunset*, a practice common in those days.[40] Over 80 years later, Rutter's turn of the century trips were compared and contrasted with a similar trip in 1981 by a member of *Sunset's* staff down a much changed Sacramento River (Anonymous, 1981).

Rutter (1903c) deserves mention for his turn of the century whimsical look at the fishes of the Sacramento River. Entitled "Proceedings of the XIIIth Conclave of the N.F.G.W. [=Native Fishes of the Golden West]", this is really a play on words for "Native Sons (or Daughters) of the Golden West," a local patriotic organization consisting of members descended from pioneer individuals born in California. Brimming with Rutter's keen sense of humor and his own hand-drawn illustrations and photographs, it provides insight into some of the major ichthyological disagreements of that time.

It further expresses his feelings about the introduction of alien fishes in California waters (similar arguments about alien minorities were often heard at contemporary Native Sons of the Golden West conclaves), and some of his colleagues in ichthyology. Most revealing is the statement about his major professor Charles Henry Gilbert with regard to whether steelhead and rainbow trout should be considered as one or two species: "Dr. Gilbert's word is law; that settles it" (Rutter, 1903c:378). Publication of the entire article in *Out West* was apparently encouraged by one of Rutter's mentors, David Starr Jordan, who was a senior editor on the staff of the magazine and equally well known for his own keen sense of humor (Evermann, 1930, 1931).

[40]The practice of USFC workers getting paid for submitting manuscripts to popular magazines for work conducted under government auspices was apparently encouraged by federal authorities as an accepted way of disseminating important fisheries information to the lay public, as well as providing some extra income to the author. Apparently the only requirement was the written permission of the Commissioner. Today, such actions would be considered a conflict of interest by federal authorities.

Rutter's lament about the introduction of a wide number of fishes from the eastern United States into California (Rutter, 1908) is important because he is apparently one of the first fisheries biologists to note a possible problem with introduced fishes adversely affecting the native ichthyofauna. Today, introduced fishes (in concert with habitat change or loss) are directly responsible for the decline and extinction of a number of native fishes in California and other western states (Moyle, 1976, 2002; Moyle and Williams, 1990; Minckley and Deacon, 1991).

From July to September 1902, Rutter assisted Charles Wilson Greene (of the University of Missouri) with his second summer of biological investigations on the physiology of Chinook salmon in the ocean (at Monterey), the lower Sacramento River (at Black Diamond), and on their spawning grounds (at the McCloud River Fish Hatchery) (Anonymous, 1902b; Smith, 1905; Fig. 16). The results of their work revealed several changes in the physiology of salmon throughout the fishes' life cycle (Greene, 1905).

By the fall of 1902, Rutter was actively searching for new challenges to study with the completion of his California salmon studies. He even wrote to his old friend John Pease Babcock (who was now head of the Provincial Fisheries Department of British Columbia) asking if there were any chances for employment with his office. However, Babcock was still trying to recover from a recent fiasco with the CSBFC, and he suggested that as soon as his affairs were settled he would then make Rutter an offer worth considering. In the meantime, Babcock suggested that it was best for Rutter to go ahead and try for another job elsewhere.[41]

Thus, from September through mid-November 1902, Rutter continued to work on supplementary studies with Chamberlain on the movements of salmon in the Sacramento River basin

[41]18 Sept. 1902 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

Figure 16.—Rutter with two Chinook salmon during 1902 near Monterey, California. Original photo to courtesy of Richard R. Rutter.

(Smith, 1905; Jennings, 1987). They also conducted laboratory experiments on the deleterious effects of light on developing salmon embryos at Battle Creek Hatchery (Smith, 1905).

In mid-September, Rutter wrote to his mother about the difficulties of tagging fish in the field, specifically, "Chamberlain is with me now, and we are having some very hard work. The creek is in a deep can[y]on, and we have some hard climbing to do to say nothing of being in the water, and the water is cold. We don't get in deep, though. We are catching salmon and tagging them to see how far they go down stream before dying, and as the stream is very rough we are having a hard time catching them. The stream is exceedingly rough, and the scenery the finest that I have ever seen. Either the upper or the lower half of the wall of the can[y]on is vertical and sometimes both halves in the same place. C[hamberlain] got here Monday. Tues. A.M. we went down to see the creek, and it was so fine that I could hardly get him back. Tues. P.M. and Wed. A.M. we made nets. Wed. P.M.

we took the nets to the creek. At the place that we wanted to use one of the nets the wall of the can[y]on is vertical for the lower half. Fred went down the trail to find the place where we wanted to work and I took the nets to the brink and threw them over. The first one caught on a vine and I had hard work getting it off, but finally it fell "splash" in the water a hundred feet below. The other went down without mishap. I threw them down from the base of a big tree that was growing right on the brink and even leaning over the water considerably. The tree forked near the base and I could look through the fork down to the water and see Fred pulling out the nets. I couldn't help thinking, 'What if the tree should topple over?', but as it was a green tree, there was not the slightest danger, if I had thought there was I would not have been there. Before reaching the tree I had to dispose of a small rattlesnake [=*Crotalus oreganus oreganus*], but he was not much trouble."[41]

Figure 17.—Rutter at his office desk while Curator of Ichthyology at the California Academy of Sciences during 1902. Note the fish netting, camera, and *Sunset* articles on the desk. Original photo courtesy of Richard R. Rutter.

Fisheries Steamer *Albatross* Investigations, 1902–1903

During mid-November 1902, Rutter was engaged in a study of young sockeye salmon at Baker Lake, Wash. Most of his work dealt with determining if sufficient food resources were available for the young salmon released in the lake by the nearby hatchery (Smith, 1905). Rutter completed his short investigation without incident and returned to California where he was soon offered the position as Resident Naturalist aboard the Fisheries Steamer *Albatross*. Thanks to his wife (see below), Rutter received letters of recommendation for this position from David Starr Jordan among others.[42]

Apparently his appointment was initially caused by the departure of Charles Haskins Townsend from the USFC. Townsend resigned on 11 Nov. 1902 to become Director of the New York Aquarium (Bowers, 1905b). Evermann was then promoted on 13 Nov. 1902 to Townsend's old position as Assistant in Charge of Statistics and Methods of the Fisheries (Jennings, 1997a). This resulted in Rutter's colleague Henry Frank Moore being promoted on 17 Nov. 1902 to Evermann's old position of Scientific Assistant, and Moore's old position then being offered to Rutter.

Rutter thought it over for a short time and decided that it would be a good promotion for him despite the large number of days he would have to serve on board away from his new bride (see below). Thus, he was promoted on 19 Nov. 1902 (Bowers, 1905b), with a notice published the next day in *The Daily Palo Alto* (Anonymous, 1902c), and he immediately made plans to travel to USFC headquarters in Washington, D.C., to prepare for a new season of field work.

After spending a few weeks at headquarters and Christmas with relatives in Indiana, Rutter returned to CAS (Fig. 17) where he began a survey of Alaska salmon packers and canners over the proposed 1903 salmon regulations in Alaska. He also requested information from federal and state hatchery superintendents in the Pacific States on rearing techniques for Pacific salmon in order to prepare a future manuscript on the subject. Because the USFC Commissioner was very supportive of this endeavor, it received top priority as Rutter's first assignment as Resident Naturalist aboard the *Albatross*.[43] However, a new assignment soon appeared for the USFC—one that would involve many of its best minds and associates over the next decade.

Alaska Salmon Commission Studies, 1903

Early in 1903, the Alaska Salmon Commission was formed from government and university personnel to study the acute problems of the salmon fishery of Alaska (Jordan and Evermann, 1904). This commission was one of many created during the late 19th and early 20th centuries to solve problems with dwindling commercial natural resources such as timber, fisheries, and northern fur seals, *Callorhinus ursinus*, (Jordan, 1922; Olson, 1971) and provides a classic example from the

[42]6 Oct. 1902 letter from Jordan to Effie Rutter and 8 Nov. 1902 letter from George Meade Bowers to Effie Rutter (copies in CAS Archives).

[43]Barton Warren Evermann files, box 130, "U.S. Fisheries-Cloudsley Rutter" (CAS Archives).

Progressive Era (Hays, 1959). Although there had been a number of problems with the salmon fisheries in Alaska throughout the 1890's (Moser, 1899), the large expansion of the fishery from 1899 to 1902, coupled with the ineffectiveness of Alaska salmon laws passed by the U.S. Congress, resulted in overexploitation of the fishery and the bankruptcy of a large number of fishing firms (Moser, 1902; Roppel, 1982, 1986).

At the instigation of the President of the United States, the purpose of this special commission was to determine the efficiency of the existing regulations under which the fisheries were conducted, the necessity for artificial propagation, and the submission of a report with recommendations as thought necessary for the proper regulation and preservation of these important food fishes (Roosevelt, 1904; Jordan and Evermann, 1904; Smith, 1905). Early on, it was apparent that this well-financed commission of fisheries experts would provide important information for the future regulation of the Alaska salmon industry (Jennings, 1997a). Indeed, the Commissioner of the USFC declared this "to be the most important expedition ever sent out by the Commission, and the information obtained will assist materially in developing Alaska's fisheries" (Anonymous, 1903c).

The commission was composed of 15 individuals, with Jordan as the Executive Head and Evermann as Acting Head. The others, based on information from Anonymous (1903d, 1903e), Jordan and Evermann (1904), and Smith (1905) included: Lt. Franklin Swift (Commander of the *Albatross*), Rutter (Resident Naturalist, *Albatross*), Alvin Burton Alexander (Fishery Expert, *Albatross*), Harry Clifford Fassett (Captain's Clerk, *Albatross*), John Nelson Wisner, Jr. (Superintendent of Federal Fish Cultural Stations), Chamberlain (Scientific Assistant), Clarence Hamilton Kennedy (Scientific Assistant), Edmund Lee Goldsborough (Scientific Assistant), Albertus Hutchinson Baldwin (Expedition Artist), Milo Herrick Spaulding (Scientific Assistant), Gilbert (Professor of Zoology, Stanford), Harold Heath (Professor of Zoology, Stanford), and Jordan's son Harold Bowen Jordan (Student of Chemistry, Stanford).

Figure 18.—Milo Herrick Spaulding (l) and Rutter (r) with their last load across the portage barabara on 12 May 1903 at Karluk, Alaska. Original photo courtesy of Richard R. Rutter.

Although the bulk of the commission left San Francisco aboard the *Albatross* on 11 June 1903, certain individuals left earlier to pursue certain phases of the salmon fisheries in Alaska (Schmitt, 1945). Thus, Chamberlain left in early March for Loring (on Revillagigedo Island), Rutter and Spaulding left in early April for Karluk (on Kodiak Island), and Gilbert left in early June for Bristol Bay (Smith, 1905). The rest of the commission sailed for Alaska via Seattle, Wash., on 18 June 1903 (Schmitt, 1945).

Early in the voyage, Rutter decided to keep a typed diary of his summer activities. Although a fully edited version of this diary appears elsewhere (M. R. Jennings, In prep.), it nonetheless provides an intimate view of Rutter and Spaulding's trials and tribulations in studying the life history of salmon on Kodiak Island at the turn of the century.

Rutter and Spaulding left San Francisco aboard the Alaska Packers Association's, iron-hulled *Star of Russia* on 2 Apr. 1903 and sailed for 29 days to Kodiak Island. They were both quickly overcome with seasickness on the voyage which resulted in Rutter having second thoughts about taking "the *Albatross* position." However, as the voyage progressed, their seasickness abated and Rutter soon prepared himself for 4 months of strenuous field work. Rutter and Spaulding (Fig. 18) spent most of their time gathering data on migrating juvenile and adult sockeye salmon, the food habits of resident trout and charr, and the collection of specimens of resident fishes in the Karluk River region. Since they were especially concerned about the overharvest of salmon, they also observed the work of the local cannery fishermen.[44]

Due to Rutter's previous experience at an Alaska fish hatchery, he was well acquainted with the many problems associated with working with the locals and cannery officials at Karluk. There were always the "drunks" to

[44]Alaska diary (see footnote 1).

Figure 19.—The Smith House where Rutter lived and conducted much of his laboratory work while in Karluk, Alaska during 1903. Original photo courtesy of Richard R. Rutter.

deal with, not to mention a perceived lackadaisical attitude of the local Native Americans.

For a while, Rutter had to put up with a feud between the wives of the two rival cannery stores where locals purchased their goods. This was especially vexing to him because the two cannery stores often forced Rutter to pay his locally hired assistants in scrip which could only be cashed in for goods at the particular store of issue (that is, the store owned by one of the two rival canneries). Often, his assistants (who were loyal to the cannery which hired them during the fishing season) either wanted to be paid entirely in cash, or in scrip from the cannery store they would only patronize. Thus, either way he paid his help, Rutter would end up offending one or both canneries, and he often required small favors from cannery superintendents in order to conduct his fisheries studies. However, he eventually worked out a suitable arrangement with the wife of one of the stores (by having her hire his local help) and thus was able to continue his studies without delay.

Ever the equal-opportunity employer, Rutter quickly learned to employ a couple of dependable Native Americans to collect hundreds of plants (for specimens to send to the Smithsonian Institution) and to dissect dozens of trout and charr (for food habits studies), not to mention pack in much needed materials and supplies. Such efforts provided the USFC with a good deal of important information at a fraction of the price (approximately $0.65/day vs. $8.00/day) it would cost if the USFC had paid Rutter and Spaulding to do all the work. However, Rutter lamented that his hired help did not know what to do with the good wages he paid them. When paid in scrip, his Native American workers often bought candy or flavoring extract (a common substitute for whiskey) rather than necessary supplies for their destitute families.[44]

One of the items which most interested Rutter during his stay on Kodiak Island was the unanimous belief by fishermen that resident trout and Dolly Varden charr, *Salvelinus malma*, annually preyed on large numbers of young salmon in Alaska and Canadian rivers (Foerster, 1930). This belief resulted in large numbers of trout and charr being caught by fishermen and left on nearby beaches to rot (Chamberlain, 1907). Thus, Rutter attempted to determine if these valuable food and sport fishes deserved their unflattering reputation.

He had one of his Native American assistants cut open trout stomachs and place the contents in a series of dishes for examination. Although Rutter eventually obtained enough data to indicate that resident trout and charr were not serious salmon predators, his information as published in Chamberlain (1907), was not acted upon by superiors. In fact, from 1920 to 1941, there was a bounty on Dolly Varden charr that was originally paid for by a tax on each case of canned salmon, and later by matching funds provided by Territory of Alaska appropriations and the Bristol Bay Salmon Packers' Association (Morton, 1975, 1981; Roppel, 1982). This bounty was finally eliminated by the Secretary of the Interior in 1941 (Morton, 1975), almost 40 years after Rutter's initial findings.

Rutter spent part of the spring writing reports and studying and collecting fishes in the area immediately around Karluk. While there, he lived in a boarding house [=Smith House] run by the wife of one of the cannery superintendents (Fig. 19). Since there were many rooms available for Rutter to use in the house, he soon set up his special glass aquarium in one room and took many photographs of salmon and other local fishes held in this aquarium—surely the first photos of live Alaska fishes (Fig. 20).

Rutter also spent some of his time tagging adult salmon in the Karluk River near town. Later capture of these fish by commercial fisherman revealed that adult salmon may enter salt water again or even travel to other streams up to 96.5 km (60 mi) away from the river where they were first captured (Chamberlain, 1907). This finding was important because it showed a certain percentage of adult salmon strayed from their natal streams, an idea that was vigorously denied by the local fisherman (Roppel, 1986).

Figure 20.—Adult male sockeye salmon photographed in Rutter's specially built glass aquarium during 1903 in Karluk, Alaska. Original photo courtesy of the Barton Warren Evermann Collections, CAS Archives.

Figure 21.—Rutter in mosquito netting on the road from Karluk Lake to Karluk in Alaska during the summer of 1903. Original photo courtesy of Richard R. Rutter.

During the rest of the spring and early summer, Rutter assisted Spaulding in the field where they trapped and marked young and adult sockeye salmon in Karluk Lake and its many tributaries. The strenuous work, inclement weather, and hordes of sandflies (Simuliidae and Ceratopogonidae) and mosquitoes (Culicinae) made life generally miserable, despite wearing mosquito nets, gloves, and other protective clothing (Fig. 21). Rutter spent a good deal of time writing home about fending off the hordes of biting insects—both literally and figuratively. Rutter and Spaulding subsisted largely on wild fishes and game they collected while out in the field and, because of the poor diet, exposure, and fatigue, at least part of the time they were both afflicted with various ailments and sicknesses.[44]

During their salmon studies, Rutter and Spaulding also took time to take photographs of a number of bald eagles, *Haliaeetus leucocephalus*, and their nests. The work was not without incident as some of the nests were in tall trees that had to be scaled with the aid of climbing ropes, and Spaulding suffered more than one serious fall.[44] Eventually, several sets of eggs were procured for the Smithsonian Institution from the 13 eagle nests examined. Rutter's notes and photographs of this ornithological work were published in Rutter (1903d).

As mentioned, Rutter utilized a Native American helper to assist him in collecting plants from the vicinity of Karluk. Although their modest efforts resulted in only a couple of hundred specimens being collected, Rutter was able to photograph many of the species that flowered during the summer months. According to Hultén (1969), Rutter's plant collection was an important contribution to the botany of the Karluk region.

Upon completion of the field work on 29 June, Rutter found that he had lost 6.8 kg (15 lb) due to all the exercise and physical labor. He spent the last 6 weeks exploring the local area around Karluk (searching for suitable hatchery sites) as well as writing up his report of the summer's work and a number of manuscripts for publication (Rutter, 1903d, e, f, 1904d).[45] Due to the fairly regular arrival of ships at the cannery, Rutter also wrote many letters to family, friends, and USFC officials, which he sent off on these vessels when possible.

On 21 August, Rutter left Kodiak Island aboard a salmon cannery supply boat. As the boat had to visit each of the company's canneries in Alaska, Rutter soon found himself taking a roundabout way back to Seattle. At each cannery, the ship normally took about 18 h to unload supplies and load up cases of canned salmon. Rutter thus had spare time to visit these "outposts of civilization" and made many comments on the local inhabitants. Most notable was the Port of Valdez, which Rutter described as "one of those frontier boom towns consisting of tarred paper houses and bad characters that need tarring." At Sitka, Rutter stopped by the capitol building and had a short talk with the Governor.[46]

[45]Unpublished manuscripts written at this time include: "A Report on the Methods of Propagating the Pacific Salmons" (6 pages), and "The Artificial Propagation of the Pacific Salmon in California, With Suggestions for a Home or School Aquarium" (10 pages) [Barton Warren Evermann files, box 130, "U.S. Fisheries-Cloudsley Rutter", CAS Archives].

[46]Alaska diary (see footnote 1).

Eventually, Rutter arrived in Seattle on the evening of 12 September. He quickly took the next available train home to San Francisco and began the laborious task of unpacking his equipment and specimens shipped several weeks earlier from Alaska. By this time, summaries of the findings of the Alaska Salmon Commission were being printed in the local press and in trade journals (Anonymous, 1903e, f). These were spurred by the arrival of Evermann on the evening of 14 September, Gilbert on the morning of 15 September (Anonymous, 1903e), and the *Albatross* on 24 September (Schmitt, 1945).

Jordan had apparently written a preliminary report (Jordan and Evermann, 1904) soon after his arrival at Stanford University in August, and informed the local press about the commission's findings. Additionally, Evermann informed the *Pacific Fisherman* about the commission's findings while in Seattle (Anonymous, 1903f). Both recommended that the salmon "fisheries be placed under control of expert men who may act free from political influence, and that hatcheries be established throughout the Alaskan country" (Anonymous, 1903c) to stem the decline in the annual pack of fish (Anonymous, 1903d, e, f). Interestingly enough, it was apparently Rutter's earlier, short-lived, successes in increasing salmon runs in the Sacramento River by the use of artificial propagation that convinced the USFC to advocate the widespread establishment of salmon hatcheries in Alaska (Chamberlain, 1903; Rutter, 1903g, 1904a; Jordan and Evermann, 1904).

Although the pros and cons of hatchery recovery strategies were widely debated in the 1880's and 1890's (Roppel, 1982), by the early 1900's it was the established position of the U.S. Government that fish hatcheries were the proper way to manage and sustain many of our important commercial freshwater fishes (Smith, 1910; Larkin, 1970; Nielsen, 1993; but also see Jordan, 1922, 2:135, for an early dissenting opinion). Only recently has the fallacy of this course of action become apparent for many of the salmon stocks in western North America (Lufkin, 1991; Meffe, 1992; Black, 1995; Weber, 2002).

While back in San Francisco, Rutter apparently sent his Alaska diary to his parents in Indiana and asked if they would see if their local newspaper (*The Oakland City Enterprise*) would print it.[47] He was also receiving a good deal of praise from friends, relatives, and colleagues regarding his "fish convention paper" (Rutter, 1903c), although he never thought much about it himself. Rutter was most proud of his "Chouicha article" (Rutter, 1902b) because of its comprehensiveness and readability. However, he lamented that he could not write any more papers like the above because of the lack of suitable subject matter.[48]

Work With the California Academy of Sciences

Rutter was proposed for membership in CAS by his old mentors Gilbert and Jordan on 16 Apr. 1900. In due time, he received the proper number of votes by the CAS Council and officially became a member of CAS on 17 Sept. 1900 (Leviton and Aldrich, 1997). Soon after that, Gilbert also proposed that he become Honorary Assistant Curator of Fishes at CAS, and the CAS Council once again quickly confirmed Rutter's relationship with the institution.[49] In 1901, Rutter became the Curator of Ichthyology, but the following year he became the Honorary Curator of Ichthyology (Leviton and Aldrich, 1997) because of his acceptance of the Naturalist position on the *Albatross*.

As was the practice in those early years, many curators did not receive any pay for their research (Jennings, 1997b); rather CAS provided limited funds to preserve and care for specimens under their care.[50] Thus, most of the curators at that time had other jobs such as university appointments or private medical practices to sustain themselves. Rutter was probably unique in this regard because his full-time employment outside CAS was provided by the federal government.

While at CAS, Rutter worked hard to bring its small, but steadily growing fish collection into shape by sorting, identifying, and cataloguing the many specimens which were sent to the institution. He even was able to name a couple of new species that came to his attention (Rutter, 1904f). Unfortunately, neither the specimens handled by Rutter nor the Department of Ichthyology catalogue books of 1900–03 survived the San Francisco earthquake and fire of 1906, so I have only a rough idea of the size and extent of the collections. But there is no question that Rutter helped CAS receive a number of collections from his own USFC field work (Leviton and Aldrich, 1997) and duplicate series of fishes from the ichthyological collections of Stanford University and the Smithsonian Institution.

Besides working in the collections, Rutter also found the time to give a series of lectures to the lay public about his salmon studies. As was the custom then at CAS (and remains so today), curators were encouraged to give formal presentations to fellow scientists, CAS members, and the lay public about their own research. Normally, CAS sponsored about a dozen official lectures per year by various scientists connected with the institution in the first part of the 20th century, and Rutter is known to have officially given two presentations there (Leviton and Aldrich, 1997).

It was also at CAS that Rutter met his future wife. Soon after taking up his duties in the Department of Ichthyology, Rutter began to date a young woman named Effie Ann McIllriach (1 June 1870–16 July 1922), the As-

[47] 12 Oct. 1903 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[48] 2 Nov. 1903 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[49] Unpublished records in CAS Archives.

[50] 17 Dec. 1909 letter from Leverett Mills Loomis to the Trustees of CAS (1909 Correspondence K-Z, CAS Archives).

sistant Secretary and Librarian at CAS (Leviton and Aldrich, 1997).

Rutter and his future bride mentioned their marriage intentions to relatives on 11 July 1901.[51] They were married at Plymouth Congregational Church in San Francisco on Thursday, 29 May 1902 [at 0800 h], by the Reverend Fletcher B. Cherington (Anonymous, 1902d).

After their marriage and several weeks visiting Rutter's relatives back east in Indiana, the newlyweds returned to California where they rented a place in Pacific Grove near the Hopkins Seaside Laboratory. There Rutter continued his work on the embryology of Chinook salmon (Anonymous, 1902e) and also assisted Charles Wilson Greene with his salmon physiology work in nearby Monterey (Smith, 1905). Later that same year they moved back to Effie's mother's house at 1014 Golden Gate Avenue in San Francisco (Crocker Company, 1903) from which Rutter worked on fishes at CAS and on field expeditions in California and Alaska.

Soon after Rutter's return from Alaska in the fall of 1903, his only child, Cloudsley Damon Rutter, was born in San Francisco on 1 Oct. 1903—an event that induced more than a few mental lapses with the proud father.[52] According to Rutter, he had his father's big ears and crooked little fingers, and also showed signs of being a very smart boy.[53] Unfortunately, Rutter's joy at raising a family was to be all too brief.

Last Days

On 12 Oct. 1903, Rutter received a letter from Evermann indicating a possible reassignment back east to Washington, D.C.[53] He was to write up more reports on his salmon work in Alaska[54], help work up season's collection of Alaska fishes, and also prepare for a new season of field activities on the *Albatross*.[55] Rutter looked forward to transferring back to the U.S. Bureau of Fisheries (USBF)[56] headquarters and started making plans to have his family leave San Francisco about December 6th and travel by railroad through the southern part of the United States via El Paso, Texas, and Kansas City, Missouri.[57]

Later that month the assignment became official (Chamberlain, 1904) and Rutter made plans to stop off at his parent's place in Oakland City, Ind., for a week or two and then leave his wife and baby at his sister's place until he could find a house for them in Washington, D.C.[58] However, his mother became seriously ill and died on 8 November, so Rutter asked for a couple of weeks off to deal with the crisis. With the blessing of his superiors, Rutter, his wife, and their new baby took the train to Oakland City and prepared for Rutter's impending move to Washington, D.C.

Unfortunately, Rutter never got the chance to do anything further. Despite several train delays in route, he and his family arrived in time [on 13 November] for his mother's funeral on 20 November. However, the trip was understandably very stressful for Rutter and he was exposed to a number of colds.[59] Soon after, he started showing the symptoms of erysipelas on 18 November.[60] According to official medical records, Rutter contracted this disease while traveling on the train from California to Indiana.[60]

The disease was first noticed as a small black spot on the end of his nose and quickly spread over the rest of his face so that he had to cover this up with wet gauze.[61] For nearly 2 weeks he raved in delirium despite the best efforts of the local physicians and trained nurses.[62] Tragically, Rutter never regained consciousness and he died at 0105 h on Sunday, 29 Nov. 1903 at Oakland City, Ind., as a result of heart failure due to the effects of erysipelas complicated by heat exhaustion.[63]

Only 36 years old at his death, his grieving family was forced to hold a second memorial service barely a week and a half after his mother's interment. Rutter was buried next to his mother on 31 Nov. 1903 at Walnut Hill Cemetery near Oakland City (their names are carved on the same headstone).

Rutter's sudden death came as quite a shock to Chamberlain, Evermann, Jordan, and other USFC employees (Chamberlain, 1904), as well as those individuals who knew him personally and held him in the highest regard ([Mayer], 1904). According to Evermann, "the loss is a severe one, not only to us personally, but the Bureau and to scienc"[64], a view also shared by Chamberlain (1904) and [Mayer] (1904). It eventually fell to Evermann,

[51]11 July 1901 letter from Rutter to his father, George Rutter, and sister, Fanna Rutter (copy in CAS Archives).

[52]2 Oct. 1903 letter from Rutter to Jordan (David Starr Jordan Papers, LSJU Archives, Roll 38, p. 16).

[53]12 Oct. 1903 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[54]Rutter had already written up a 48-page typewritten report on his Karluk sockeye salmon work which was later edited and annotated by Chamberlain [see "Field Notes by Cloudsley Rutter on his Karluk work of 1903" (Barton Warren Evermann files, box 130, "U.S. Fisheries-Cloudsley Rutter", CAS Archives)]. Parts of this work were eventually published in Chamberlain (1907).

[55]29 Oct. 1903 letter from Evermann to Jordan (David Starr Jordan Papers, LSJU Archives, Roll 38, p. 218–219).

[56]The USFC was reorganized under the Department of Commerce and Labor as the United States Bureau of Fisheries on 1 Sept. 1903.

[57]2 Nov. 1903 letter from Rutter to his mother Hanna Rutter (copy in CAS Archives).

[58]23 Oct. 1903 letter from Rutter to his uncle Lem[uel Emmerson] and 4 Nov. 1903 letter from Rutter to his sister, Fanna Rutter (copies in CAS Archives).

[59]3 Dec. 1903 letter from Effie Rutter to Jordan (David Starr Jordan Papers, LSJU Archives, Roll 38, p. 523–524).

[60]Certified Death Certificate for Cloud Rutter (Record Number 500), Division of Vital Records, Indiana State Board of Health, Indianapolis.

[61]Reminisces of Rutter's niece, Ramona Fanna (Holt) Winchell (via RRR, pers. comm.).

[62]3 Dec. 1903 letter from Effie Rutter to Jordan (David Starr Jordan Papers, LSJU Archives, Roll 38, p. 523–524).

[63]The date of Rutter's death has been erroneously published as "Oct., 1903, "26 Nov. 1903," "28 Nov. 1903," or "30 Nov. [1903]" (Anonymous, 1903a, b, 1910, 1921, 1932; [Mayer], 1904; Bowers, 1905a).

[64]3 Dec. 1903 letter from Evermann to Jordan (David Starr Jordan Papers, LSJU Archives, Roll 38, p. 519).

Chamberlain, Spaulding, and other coworkers to review Rutter's Alaska work and finish up his reports (Chamberlain, 1907; Jennings, 1987). Several Rutter manuscripts dealing with salmon culture and other fisheries subjects were never published, although an important paper on the fishes of the Central Valley of California eventually appeared in print (Rutter, 1908).

After Rutter's death, his wife Effie returned to San Francisco on 18 Dec. 1903 and attempted to put her life back together. Chamberlain records visiting her on the evening of 11 Jan. 1904[65], and it must have been difficult for him to have the unenviable duty of going through her deceased husband's effects for items relating to Rutter's work with the USFC.

Conclusions

Although very much a product of the Progressive Era, Rutter was truly a pioneer in the study and culture of Pacific salmon in California and Alaska, and he represents the prototype of modern research fisheries biologists and fisheries administrators of the 20th century. Although a few of his observations regarding the spawning activities and homing abilities of sockeye and Chinook salmon have been shown to be incorrect (Hedgpeth, 1941; Foerster, 1968), and his unwavering defense of hatcheries as a major tool in augmenting declining salmon runs has lately been found to be unjustified (McEvoy, 1986; Meffe, 1992; Black, 1995), the vast majority of his work has withstood the test of time and continues to be cited by current workers (Healey, 1991; Mills et al., 1996; Moyle 2002).

Indeed, much of our current information on the ecology of Chinook salmon is historically rooted in his landmark studies with Norman Bishop Scofield, and an ever increasing number of present-day naturalists have come to rely upon his natural history observations for an insight into the Sacramento-San Joaquin River ecosystem at the turn of the previous century. His work on Pacific salmon hatchery methods resulted in the major discovery of an artificial method of fertilizing eggs in a saline solution, a technique which greatly increased fertilization rates ([Mayer], 1904) and is now considered standard in trout and salmon culture (Leitritz and Lewis, 1976).

Although Rutter described a modest number of new species of fishes[66], and only had one fish named in his honor (Gilbert and Snyder, 1898), he nonetheless made important contributions to ichthyology during his remarkably short lifetime. Other scientists recognized his contributions and he was listed (as deceased) in the first edition of *American Men of Science* (Cattell, 1906).

Always interested in educating the public to the benefits and problems of America's fisheries resources, his series of popular publications for the lay person were important methods of communication in the days before radio and television and remained widely cited even decades after his death. Ever ambitious and enthusiastic about his work, his high scientific and moral standards endeared him to many who came to know him ([Mayer], 1904). Although somewhat susceptible to harsh environmental conditions in the field, Rutter nonetheless persevered and even came to joke about his predicaments with the elements and its associated insect fauna. Had he been able to continue his studies, he doubtless would have become one of the most important and influential fisheries biologists of the 20th century.

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[65]Chamberlain diary, 1903–04 (see footnote 32).

[66]Rutter described 27 new species, 3 genera, and 2 families of fishes. By my count, 23 species and 2 generic names are presently valid, and one of the family names has been placed in synonymy. The other family name (SIGANIDAE Rutter 1897) has been proposed to be placed on the Official List of Family-Group Names in Zoology by Nielsen and Klausewitz (1968) as Case 1721 to the International Commission of Zoological Nomenclature. This case is apparently still pending.

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Development and Trial of Deep-set Buoy Gear for Swordfish, *Xiphias gladius*, in the Southern California Bight

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Introduction

Several management concerns have been raised over swordfish, *Xiphias gladius*, fisheries and their interactions with nontarget species (Carretta et al., 2003; Gilman et al., 2006). Within the U.S. west coast Exclusive Economic Zone (EEZ), swordfish are landed domestically by the California Drift Gillnet (DGN) fishery and, to a lesser extent by a small southern California-based harpoon fleet (Bedford and Hagerman, 1983). The remaining domestic demand for swordfish is met annually by imports from the Hawaii shallow-set longline fishery and from foreign longline fleets (Bartram and Kaneko, 2004; PFMC, 2011).

Off California, DGN interactions with nontarget species of concern (e.g., marine mammals, Physeteridae, and sea turtles, Dermochelyidae) have spurred numerous restrictions that have directly affected local fishermen through time and area closures (including the ~200,000 nmi[2] Pacific Leatherback Closure Area (PLCA)) and mandated gear and operational modifications (Hanan et al., 1993; Carretta et al., 2003; PFMC, 2011; Benson et al.[1]).

Despite recent information that suggests a healthy and underexploited population of north Pacific swordfish (Brodziak and Ishimura[2]), a consistent decline in DGN participation and ex-vessel revenues has ensued over the past 30 years. In 2012, DGN operations reached historic lows in both landings and participation, with fleet operations restricted to the Southern California Bight (SCB), a relatively small portion of the former fishery range (PFMC, 2013). These declines have resulted in adverse economic impacts on ports and associated businesses located adjacent to the PLCA (e.g., Morro Bay and Monterey) and have consolidated effort to a small geographic region that has been shown to historically fluctuate in swordfish landings (Bedford and Hagerman, 1983).

Commensurate with the decline of DGN operations off California, traditional harpoon fisheries have also dwindled, with effort and landings also reaching their lowest points in over three decades (PFMC, 2013). This decline has occurred despite the open-access nature of the harpoon fishery and the local market void produced by the reduction of DGN operations.

Several factors account for the decline in the harpoon industry, including the rise in operational costs (i.e., fuel prices), inconsistent catch rates, and the lack of new entrants into the fishery. Because harpoon operations require relatively calm conditions, this fishery has historically been limited to the waters of the SCB with landings

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[1]Benson, S., H. Dewar, P. Dutton, C. Fahy, C. Heberer, D. Squires, and S. Stohs. 2009. Swordfish and leatherback use of temperate habitat (SLUTH): Workshop Report. *In* H. Dewar (Editor), U.S. Dep. Commer., NOAA, SWFSC Admin. Rep. LJ-09-06, La Jolla, Calif.

[2]Brodziak, J., and G. Ishimura. 2010. Stock assessment of North Pacific swordfish (*Xiphias gladius*) in 2009. U.S. Dep. Commer., NOAA, NMFS, Pacific Islands Fish. Sci. Cent., Admin. Rep. H-10-01, 37 p.

ABSTRACT—Fishery interactions with nontarget species (including U.S. federally protected sea turtles and marine mammals) have severely impacted U.S. west coast swordfish, Xiphias gladius, *fisheries and have hindered the development of alternative domestic operations. This study used swordfish depth distribution data to aid in the design of deep-set fishing gear to target swordfish in the Southern California Bight (SCB). To minimize nontarget interactions, the deep-set gear was designed to fish at depths between 270 and 320 m during daylight hours. The deep-set buoy gear (DSBG) configuration consisted of a vertical mainline (2.2 mm monofilament) affixed with a 4 kg weight and two 8 m gangions (1.8 mm monofilament), each rigged with an 18/0 circle hook and baited with mackerel,* Scomber *spp., or squid,* Illex *spp., or* Dosidicus gigas.

Surface floatation included a 36 cm diameter (21 kg) longline float and two smaller (3 kg) strike indicator floats. Experimental fishing trials were conducted using ten individual pieces of DSBG deployed simultaneously. Soak duration was maintained at 4 h/set and the gear was hauled immediately upon detection of a strike. Gear trials were conducted within the SCB from August to January of the 2011 and 2012 swordfish seasons from both research and cooperative fishing vessels. From 54 sets (4,320 hook-hours), 14 swordfish were captured without any interactions with bycatch/nontarget species of concern (i.e., sea turtles and marine mammals). Additional species captured during the trials included: bigeye thresher sharks, Alopias superciliosus *(7); opah,* Lampris guttatus *(2); blue sharks,* Prionace glauca *(2); and common thresher shark,* Alopias vulpinus *(1). These data suggest that deep-set fishing operations can selectively target swordfish during the day within the SCB and provide a basis for further testing using commercial applications.*

Table 1.—Information from 5 swordfish tagged using PSAT's.

Swordfish tag #	Location lat./long.	Displacement (km)	Est. mass (kg)	Days at liberty	Avg. day depth (m)	Avg. day depth below the thermocline (m)	Thermocline depth (m)	Avg. night depth (m)	Basking events
2	33° 17.08 117° 47.53	21	110	5	196	291	59	8	7
1	33° 06.23 117° 26.55	41	90	5	209	268	68	12	3
7	33° 06.97 117° 58.09	1	70	1	177	209	66	n/a	1
6	32° 52.32 117° 19.33	27	110	2	152	237	70	66	0
4	33° 17.09 117° 47.52	22	130	4	226	275	73	6	4

largely dependent on environmental conditions (Bedford and Hagerman, 1983).

The development and use of alternative swordfish gears within the west coast EEZ is complicated by several factors including the presence of a juvenile shark rookery (Hanan et al., 1993), spatial overlap with several species of concern (i.e., sea turtles and marine mammals; Carretta et al., 2003), and California's long-standing prohibition of pelagic longline gear within the EEZ (Obrien and Sunada, 1994; PFMC, 2012). Collectively these obstacles have prevented the development of alternative gear types more commonly used in global fisheries for swordfish (e.g., pelagic longline) and have resulted in the under-utilization of the west coast swordfish resource (Brodziak and Ishimura[2]). The reduction in domestic landings have also increased the reliance upon foreign swordfish imports to accommodate domestic demand (Rausser et al., 2009).

Given the continued decline of swordfish fisheries within California waters, recent work has highlighted the use of depth distribution and vertical niche partitioning of target and nontarget species for fishery development (Sepulveda et al., 2010; Benson et al.[1]). Despite spatial overlap with numerous species, recent swordfish tagging data suggest that daytime depth segregation within the SCB provides an opportunity to target swordfish selectively while simultaneously avoiding nontarget species of concern (Sepulveda et al., 2010; Dewar et al., 2011). Using depth to selectively target a specific catch has been examined in several commercial fisheries around the globe (Suzuki et al., 1977; Beverly and Robinson, 2004; Shiode et al., 2005; Beverly et al., 2009), but has only recently been considered to be an option for the U.S. west coast swordfish fishery.

Given the extreme diurnal segregation exhibited by swordfish when compared to most species of the SCB (including sea turtles (Eckert, 1999; Polovina et al., 2003; Polovina et al., 2004)), this study 1) designed a deep-set daytime gear configuration (deep-set buoy gear (DSBG)), and 2) tested the hypothesis that DSBG can effectively target swordfish while simultaneously avoiding nontarget species of concern.

Materials and Methods

Prior to the initiation of any experimental trials, an Environmental Assessment was performed by NOAA's NMFS Southwest Regional Office (SWRO). All experiments were conducted under California Department of Fish and Wildlife Scientific Collection Permits (SPC-2471, 5463) and in accordance with a NOAA Letter of Acknowledgement. Gear development and experimental deployments were performed from June 2010 through November 2012 in the SCB. Experimental trials and gear deployments were performed from the Pfleger Institute of Environmental Research vessel *Malolo* (14 m power vessel equipped with a swordfish harpoon plank) and the federally permitted commercial fishing vessel *Gold Coast* (13 m DGN/harpoon vessel).

PSAT Tagging

To design DSBG, validate target-species (swordfish) depth and concurrently tailor gangion depth, Wildlife Computers (Redmond, Wash.[3]) Mk 10 pop-up satellite archival tags (PSAT's) were deployed on five swordfish caught using both harpoon and DSBG techniques (Table 1). Tagging efforts were performed prior to and during the DSBG trials aboard the R/V *Malolo* using protocols outlined in Sepulveda et al. (2010).

Briefly, swordfish were spotted at the surface using stabilized binoculars, and the PSAT was inserted into the dorsal musculature from an extended bow pulpit using a modified harpoon and tag applicator. Similarly, swordfish captured during the DSBG trias were leadered and brought alongside of the vessel and a tag was inserted proximal to the base of the dorsal fin. Tag deployment duration ranged from 1 to 5 days, and all tags were recovered using a radio signal direction finder (Sepulveda et al., 2010). Data were downloaded at sea and DSBG configuration was adjusted accordingly.

Depth data were assessed for average daytime depth as well as the average depth below the thermocline in accordance with previous studies (Sepulveda et al., 2010). Thermocline depth was verified by visual inspection

[3]Mention of trade names or commercial firms is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

of the depth and temperature plots for each fish. Cumulative depth plots of the joint distribution of depth and time over a 24 h period were constructed using MatLab (R12). Basking events were defined as daytime depth records in which tagged swordfish were within 3 m of the surface, and successive events were defined as periods in which the swordfish traversed the thermocline and subsequently returned to the surface (<3 m).

Experimental Gear Design

The DSBG design used in this study was derived from existing commercial gear configurations used in the federally authorized Florida shallow-set buoy gear fishery (NMFS, 2010) as well as South Pacific vertical longline fisheries (Preston et al., 1998). Additional information from consultations with active California DGN participants as well as depth distribution statistics for swordfish and other species that coinhabit the SCB (previous studies and concurrent short-term PSAT deployments) were also used to tailor DSBG configuration (Holts and Bedford, 1990; Sepulveda et al., 2004; Sepulveda et al., 2010; Cartamil et al., 2010; Dewar et al., 2011).

The DSBG configuration consisted of a three-float system which included two strike-indicator floats (3.2 kg) and one 36 cm diameter (21 kg), noncompressible longline float. For most deployments, the configuration also included a hi-flyer locator flag, radar reflector (Mobri Marine, Den.) and strobe (OPI, Strobe-CH-201) to prevent gear loss (Fig. 1). Collectively, each piece of DSBG included from 270 to 320 m of 2.2 mm monofilament mainline rigged with two monofilament ganions and drop sinker. Drop sinker mass was chosen based on initial trial sets with sinkers ranging from 2 to 6 kg in mass (see Results).

Two monofilament gangions branched from the mainline, one at the base and the other approximately 30 m above (Fig. 1). Gangions were 8 m in length and constructed of 1.8 mm monofilament leader containing a crimped 18/0 circle hook (Mustad model 39960D) baited with either squid, *Illex* spp. or *Dosidicus gigas*, or mackerel, *Scomber* spp. Battery-operated illumination (Power Light, SNL Corp., Fla.[3]) was used at the juncture of the mainline and gangion, with alternating green and blue colors similar to protocols used in the Florida shallow-set buoy fishery (Burlew[4]). One full set of DSBG was defined as 10 individual pieces of gear deployed simultaneously (20 hooks/set).

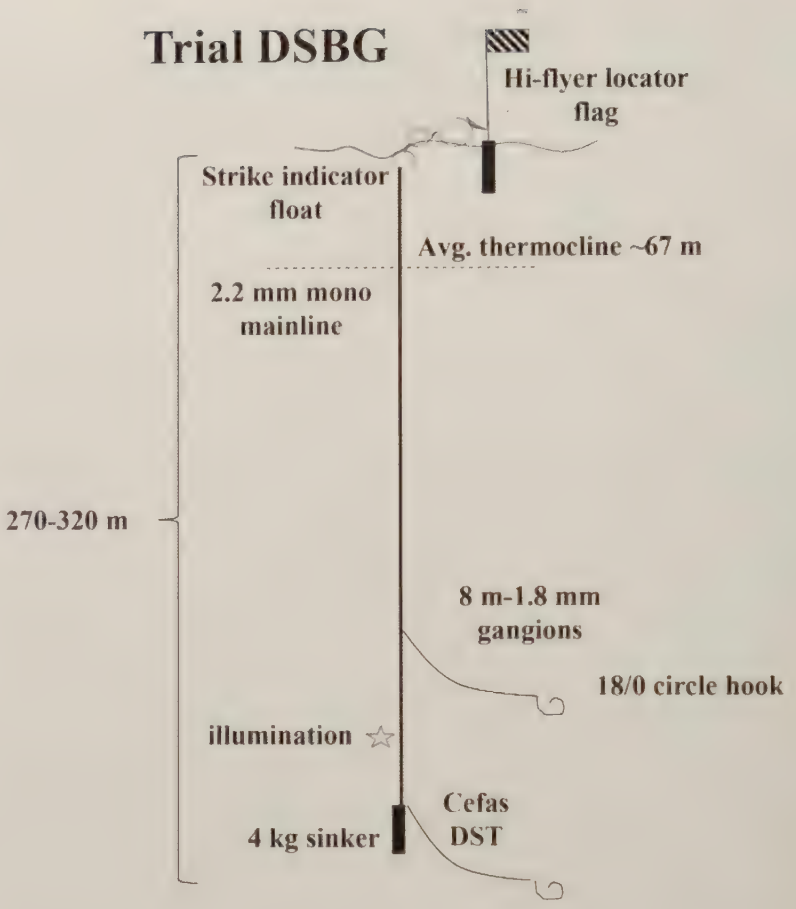

Figure 1.—Diagram of the DSBG configuration used in this study. Average thermocline obtained from PSAT tagged swordfish indicated by dashed line. Gear details are further described in the Experimental Gear Design section.

Gear Deployment Protocol

DSBG was deployed along a 3 km path at a consistent heading to ensure that the gear was visible by the fishing vessel at all times. Initial test sets were deployed with data storage tags (Cefas, Suffolk, U.K.) affixed to the gangion swivels to ensure that the gear did not drift into the upper water column or descend at a rate that would facilitate nontarget interaction (Fig. 2). Set locations were based on concurrent harpoon and DGN operations as well as satellite imagery (i.e., sea surface temperature (SST) charts and chlorophyll concentration images) and locations in which basking swordfish were observed.

Once deployed, DSBG was continually monitored using stabilized binoculars (Fujinon S-1640, 16X). Set duration was defined as a 4-h soak period in which all 10 pieces of DSBG were deployed simultaneously. The

[4]Burlew, C., Deerfield Beach, Fla. Personal commun., May, 2011.

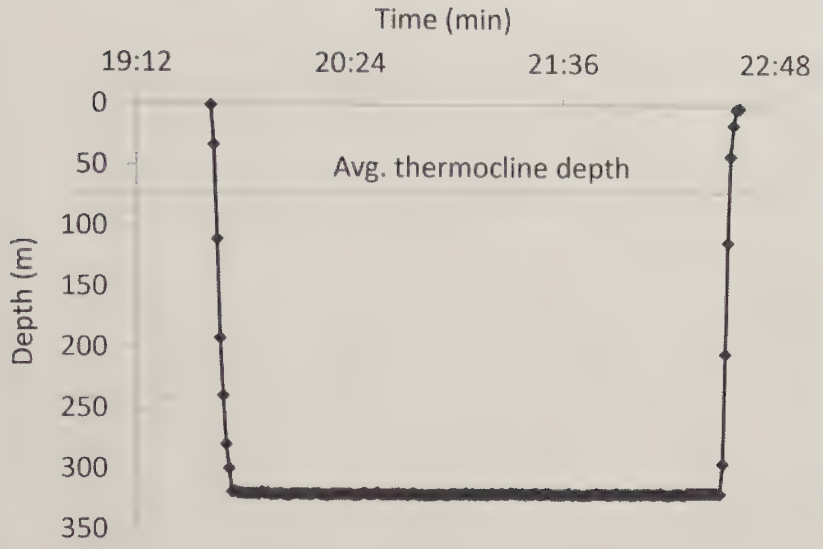

Figure 2.—Plot of the test deployments using 4 kg of lead. Plot illustrates gear sink rates that are sufficient to position hooks below the average thermocline depth in <1 min. Once at the target depth, the gear is maintained at a relatively constant position throughout the deployment period.

gear was pulled immediately upon detection of a strike, which was identified through the misalignment of the gear (due to the captured species' swimming effort) or by the floatation of the strike indicator float. Once hauled, the piece of gear was rebaited and subsequently deployed for the remainder of the set period. DSBG was hauled using either an electric or hydraulic Custom Sea Gear reel (Blue Ocean Tackle, San Diego, Calif.).

Detailed records collected for each trial included capture locations, disposition of catch, bait type, gear configuration, set duration, depth fished, and environmental conditions (i.e., current direction, SST, water color, dissolved oxygen concentration). Catch condition was assessed upon capture using metrics previously defined by Obrien and Sunada (1994).

"Good" was used to represent individuals that were hooked in the mouth, had no obvious signs of trauma, and were vigorous upon release; "Poor" was used to characterize individuals hooked in the gut or esophagus, lethargic, and showing obvious signs of stress; and "Moribund" was used for fish that were severely lethargic or dead. Successful captures were defined as any instance in which the 8 m gangion was in hand and the fish could be visually identified by the crew.

Results

Initial experiments were performed in July 2011 to identify appropriate drop-sinker mass and to develop the deployment protocol that resulted in the least tangling of the gear. A 4 kg drop sinker was determined to be adequate for sinking the gear below the thermocline within 1 min and maintaining the hooks at a constant depth throughout the deployment period (Fig. 2).

Experimental Deployments

Experimental gear trials were conducted within the SCB from August to January 2011 and August through October of the 2012 swordfish seasons. Collectively, this study deployed 54 sets of DSBG resulting in 4,320 hook-hours in the SCB (Fig. 3). Thirty nine of the sets were performed aboard the R/V *Malolo* and 15 aboard the F/V *Gold Coast*. The total drift distance of each 4 h set ranged from 0.4 to 6.1

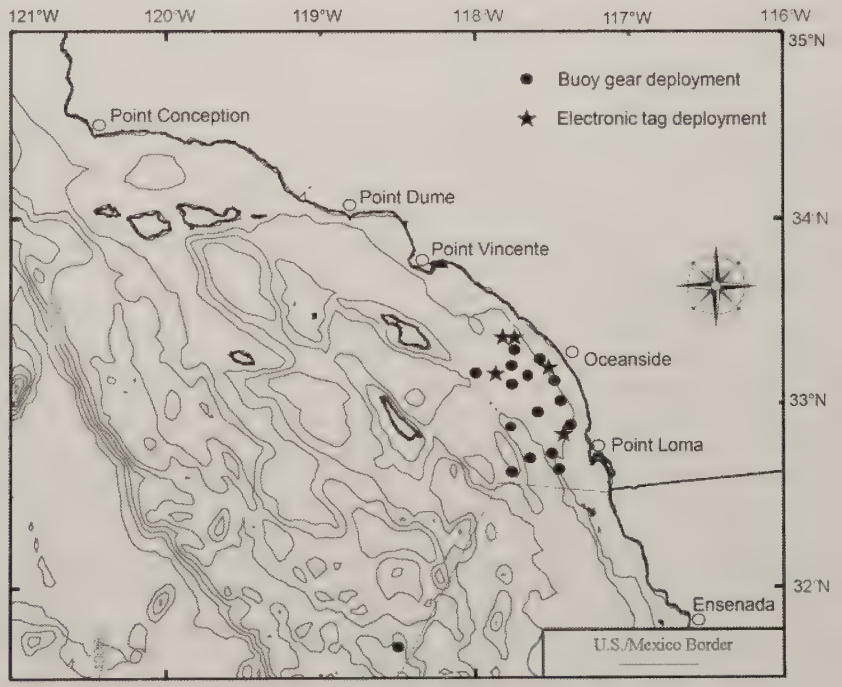

Figure 3.—Study area showing the DSBG deployments (circle) and location of the swordfish tagged in this study (star).

km and averaged 2.13 ± 1.2 km. Sea surface temperature ranged from 15.8° to 23.9°C and averaged 21.3° ± 1.8°C. Average set duration was maintained at 4 h and ranged from 3.5 to 5 h.

Catch Details

A total of fourteen swordfish were captured without any interactions with nontarget species of concern (i.e., sea turtles and marine mammals). Swordfish mass (estimated using Uchiyama et al., 1999) ranged from 90 to 195 kg round weight (RW) with an average length of 200 ± 20 cm lower jaw fork length (LJFL). Average swordfish capture depth was 299 ± 8 m. Of the 14 swordfish captured, 10 individuals were caught using green lights and four with blue (Table 2).

Additional species captured during the deep-set trials were bigeye thresher sharks, *Alopias superciliosus* (7); opah, *Lampris guttatus* (2); blue sharks, *Prionace glauca* (2); and common thresher shark, *Alopias vulpinus* (1) (Table 2, Fig. 4).

Tagging Data

Five swordfish were opportunistically tagged within the study area during the DSBG deployments (Fig. 3, 5; Table 1). The average daytime depth for all swordfish tagged in this study was 192 ± 25 m while the average night depth was 23 ± 28 m. The average depth while below the thermocline (excluding periods of ascent, descent, and basking activity) was 256 ± 32 m.

For all five swordfish, average thermocline depth was 67± 5 m (Table 1). Basking events were observed in four of the five tracked individuals and collectively accounted for 9 (± 8%) of the daily daytime records. Total horizontal displacement ranged from 1 to 41 km, with the greatest net movement being from swordfish # 05A0197 which moved on average 8.2 km/day over the 5-day deployment period (Table 1).

Discussion

This study coupled vertical distribution data from target and nontarget species with conventional fishery methods to develop and trial an alter-

Table 2.—Catch information for experimental DSBG trials in the Southern California Bight.

Species	Vessel	Capture depth (m)	~Size (FL)	Light color	Bait type	Hook location	Catch condition
Swordfish	R/V *Malolo*	300	191	Green	Squid	Lower	Good
Swordfish	R/V *Malolo*	300	165	Green	Squid	Upper	Good
Swordfish	R/V *Malolo*	300	191	Blue	Mackerel	Lower	Good
Swordfish	R/V *Malolo*	329	201	Blue	Mackerel	Lower	Good
Swordfish	R/V *Malolo*	295	211	Blue	Mackerel	Lower	Good
Swordfish	R/V *Malolo*	300	188	Green	Mackerel	Lower	Good
Swordfish	R/V *Malolo*	300	~191	Green	Squid	Lower	Good
Swordfish	R/V *Malolo*	278	231	Green	Squid	Upper	Good
Swordfish	R/V *Malolo*	300	224	Green	Mackerel	Lower	Good
Swordfish	R/V *Malolo*	295	239	Green	Squid	Lower	Good
Swordfish	R/V *Malolo*	290	198	Green	Mackerel	Lower	Good
Swordfish	F/V *Gold Coast*	300	191	Blue	Squid	Lower	Good
Swordfish	F/V *Gold Coast*	300	191	Green	Squid	Lower	Good
Swordfish	F/V *Gold Coast*	300	~191	Green	Squid	Lower	Good
Opah	R/V *Malolo*	200	109	Blue	Squid	Lower	Good
Opah	R/V *Malolo*	200	112	Green	Mackerel	Upper	Good
Blue shark	R/V *Malolo*	250	117	Green	Mackerel	NA	Poor
Blue shark	R/V *Malolo*	270	117	Green	Mackerel	NA	Poor
Common thresher	R/V *Malolo*	200	170	NA	Mackerel	Upper	Moribund
BET[1]	R/V *Malolo*	305	198	Green	Mackerel	Lower	Good
BET	R/V *Malolo*	315	~216	Green	Squid	Lower	Good
BET	R/V *Malolo*	320	163	Green	Mackerel	Lower	Good
BET	R/V *Malolo*	270	173	Disco	Mackerel	Lower	Good
BET	R/V *Malolo*	290	152	Green	Squid	Lower	Good
BET	F/V *Gold Coast*	300	~191	Green	Mackerel	Lower	Good
BET	F/V *Gold Coast*	300	~178	Green	Squid	Lower	Good

[1]BET=Bigeye thresher

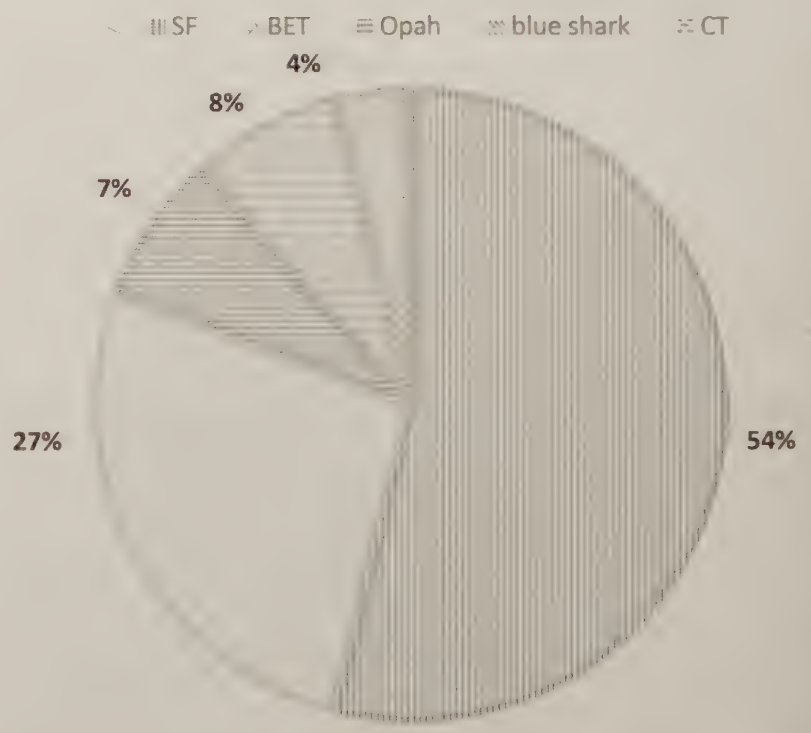

Figure 4.—Catch associated with 54 4-h sets of DSBG; SF=swordfish, BET=bigeye thresher shark, and CT=common thresher shark.

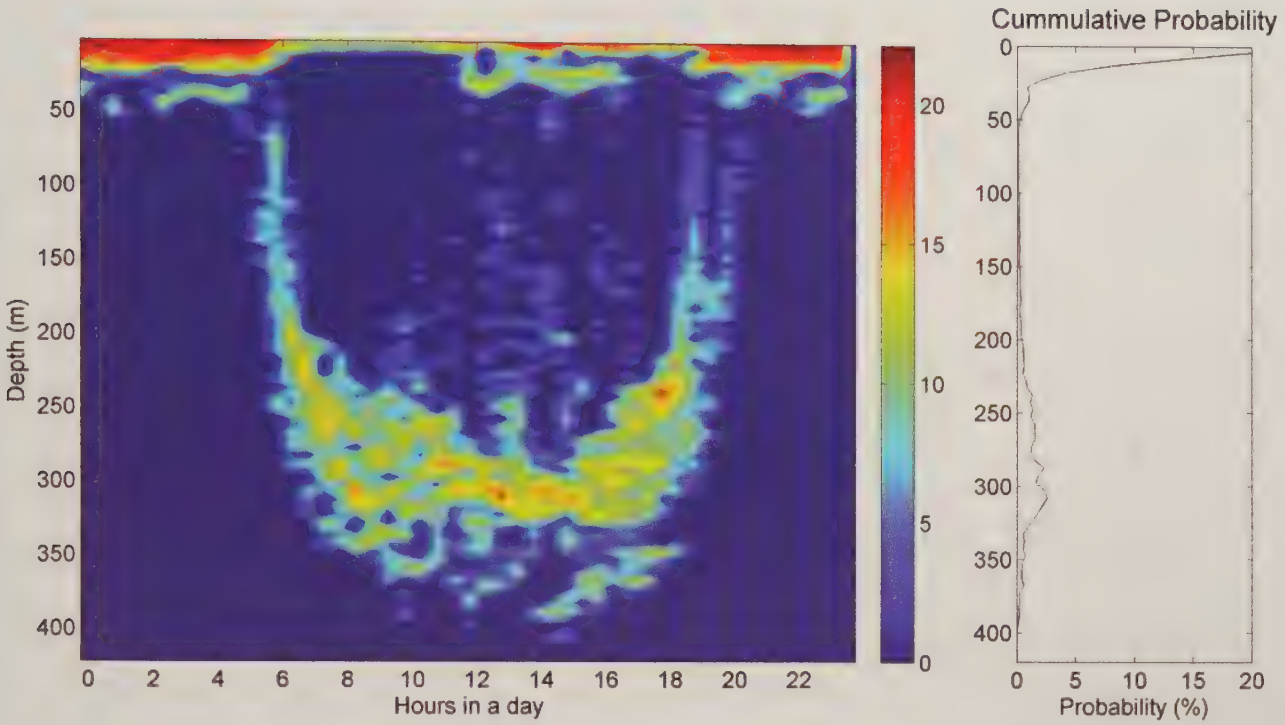

Figure 5.—Depth distribution plotted over a 24 h period and associated probability plot for 5 swordfish tagged with short-term PSAT's. Data were plotted on a log 10 scale.

native fishing gear that targets swordfish below the thermocline during the day. Findings suggest that DSBG can be used to selectively target swordfish off southern California and may provide an additional harvest method for local fishermen.

Targeting swordfish at depth also reduces the potential for interaction with species of special concern (i.e., sea turtles, marine mammals) and thus may be suitable for areas in which fleet operations are currently limited. Further, the development of selective fishing methods may lead to increased domestic opportunities for both fishermen and consumers and warrants future investigation off the U.S. west coast.

Previous Deep-set Experiments

Using hook depth as a tool to selectively target pelagic species has been used extensively in commercial fisheries for decades, with most of the effort focused on bigeye tuna, *Thunnus obesus*, and albacore, *Thunnus alalunga*, (Suzuki et al., 1977; Sakagawa et al., 1987). Although different deep-set configurations exist, hook depths are typically maintained between 50 and 300 m, which overlap with the depth distribution of targeted tuna species (Suzuki et al., 1977; Sakagawa et al., 1987; Holland et al., 1990; Schaefer and Fuller, 2002). In addition to the increased targeting of tunas, deep-set operations also have the added benefits of reduced interactions with nontarget and incidental species as well as surface oriented fisheries that may operate within the same region (Nakano et al., 1997; Polovina et al., 2003; Beverly and Robinson, 2004; Beverly et al., 2009). One drawback to deep-set operations is that they often catch fewer valuable incidental species and also incur additional cost, with more time required to set and retrieve the gear compared to surface operations (Beverly and Robinson, 2004).

Deep-set operations for swordfish are much less common, as night-based surface deployments are particularly effective for this species (Ueyanagi, 1974; Bigelow et al., 2006). Exceptions to this include deep-set operations off the coast of Australia which have successfully increased catch per unit of effort for swordfish when compared to other species (Beverly and Robinson, 2004). Also, Onada et al. (2006) have reported on a traditional deep-set vertical longline fishery that targets swordfish during the day off the coast of Japan.

The vertical longline fishery is similar in many ways to the DSBG trialed in this study; however, the vertical gear also uses surface-oriented hooks for targeting bigeye tuna and other valuable target species (Onada et al., 2006). Similarly, there are small-scale deep-set operations in use off the coast of Florida and within the Gulf of Mexico as well as in the Mediterranean Sea.

Deep-set longline trials for swordfish have also been performed off Hawaii with limited success (Boggs,

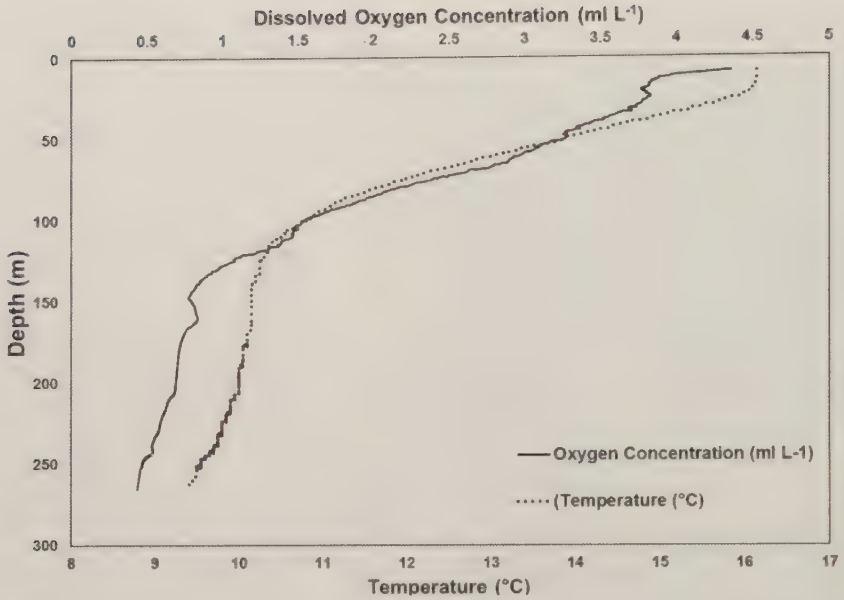

Figure 6.—Depth vs. water temperature (°C) and dissolved oxygen concentration (ml/L) collected during deep-set buoy gear trials off the coast of southern California.

2004; Gilman et al., 2007). The low success was likely influenced by the depth distribution of swordfish in this region (500–800 m; Dewar et al., 2011), which is much greater than that described for the eastern North Pacific (250–400 m; Sepulveda et al., 2010; Dewar et al., 2011).

Unlike the waters off Hawaii and the central North Pacific, the coastal waters off California exhibit a relatively shallow thermocline (67 m in this study (22–33 m; Palacios et al., 2004)) and an oxygen minimum zone (OMZ) that ranges from 250 to 500 m (Bograd et al., 2008; Fig. 6). The shallow OMZ has been hypothesized to compress the vertical habitat available for pelagic species, which concentrates pelagic resources within depths that are more accessible to modern day fisheries (Prince and Goodyear, 2006).

Catch Rates

Swordfish comprised 54% of the catch during the 2 yr project. This contrasts with previous shallow-set longline experiments that had over 90% shark catch (i.e., mako shark, *Isurus oxyrinchus*, and blue shark, *Prionace glauca*) from the same study area and during a similar time of year (Obrien and Sunada, 1994). Because the goal of this study was to design DSBG and assess the feasibility of deep-set techniques in the SCB, standard comparisons of catch per unit effort (CPUE) with other gears are not appropriate. Regardless, initial catch rates were positive, considering the poor swordfish landings observed in both the California DGN and harpoon fisheries during the duration of this study (PFMC, 2013).

In 2012, the harpoon fishery had a total catch of about 5 t from a fleet of about 25 permitted vessels (Pacific Coast Fisheries Information Network, PacFIN data query, 5/2013[5]). Further, in 2012 there were more individual swordfish captured using DSBG than landed by any one harpoon vessel.[5] Similarly, the California DGN fleet had low catches in 2012, with about 75 t landed for 15 active vessels.[5] The majority of the DGN harvest in 2012 came from outside of the area in which these experimental trials were conducted (northern portions of the SCB).[5]

[5]PacFIN data query accessed on 5/2013 (http://pacfin.psmfc.org/pacfin_pub/data.php).

The ratio of target to nontarget catch during experimental trials suggests DSBG to be relatively selective for swordfish with overall low nontarget catch rates (Fig. 4). Bigeye thresher sharks made up the bulk of the nontarget catch (Fig. 4). The bigeye thresher shark is a relatively common nontarget species of the California DGN fishery that is not typically retained for sale given their low market value when compared to swordfish and other species captured in the fishery (Hanan et al., 1993; PFMC, 2006).

Nonetheless, the bigeye thresher shark is occasionally retained and processed by local fresh markets in the United States and Mexico (Hanan et al., 1993). Because bigeye threshers are common inhabitants of the SCB that share similar diel distributions with swordfish (Nakano et al., 2003; Weng and Block, 2004), interactions with deep-set operations are likely unavoidable without additional information on their specific movements within the SCB.

Additional nontarget species captured in the trials were opah (2), blue shark (2), and common thresher shark (1), which collectively accounted for less than 20% of the total DSBG catch. All of the nontarget species encountered in this study are common in the California DGN fishery, with opah and common thresher sharks providing valuable revenue as secondary and tertiary targets of the fishery (Hanan et al., 1993).

Among the total catch, the common thresher shark was the only mortality observed during the DSBG trials. This is likely because the common thresher shark was landed by the caudal fin, a capture method that has been shown to result in increased mortality in this species (Heberer et al., 2011). The ability to detect strikes and the rapid processing of hooked fish, likely led to the overall good condition of the captured fish in this study (Table 2). The ability to release fish in good condition may provide an additional opportunity for fishermen to reduce gear impacts on nontarget species.

Movements

The depth records from the five swordfish tagged in this study were similar to those presented in previous swordfish movement studies for this region (Sepulveda et al., 2010; Dewar et al., 2011). For all individuals, the predominant depth distribution consisted of a diurnal pattern in which the swordfish remained largely below the thermocline during the day and within the upper mixed layer at night (Fig. 5). This distribution has been suggested to be in response to the diurnal movements of prey species that make up the deep scattering layer (DSL) (Carey and Robison, 1981; Carey, 1990; Takahashi et al., 2003; Sepulveda et al., 2010).

Daytime basking events occurred in all tag records and collectively accounted for less than 10% of the daytime depth distribution. This finding was similar to that of previous studies by Sepulveda et al. (2010) and provides insight into the difficulty associated with augmenting domestic landings with harpoon-based operations alone. We acknowledge, however, that in certain areas and time periods, basking behavior may be more prevalent than that observed in this study. This is evident in historical harpoon fishery records off California which show some years to be exceptionally productive for harpoon fishermen (Bedford and Hagerman, 1983). The presence of periodic basking activity supports hypotheses on behavioral thermoregulation (Takahashi et al., 2003, Sepulveda et al., 2010), and remains an important factor in understanding fishery dynamics and the limitations of harpoon operations.

Applicability and Limitations

Given that DGN operations are particularly effective in targeting swordfish off California with a relatively small net length (<1,000 fm or 1 nmi: Hanan et al., 1993), it may be that the coastal aggregation of the swordfish resource in the eastern North Pacific provides suitable conditions for buoy-based fisheries to operate. Despite positive results from the initial trials performed in this study, DSBG operations are artisanal in nature and present several limitations when compared to higher capture-volume gears such as DGN and pelagic longline.

Among the limitations are the low number of hooks deployed at a single time and the need for continued monitoring of the gear. These traits reduce the ability of the gear to operate on a larger scale, and therefore concentrate fishing effort within a relatively small (3–4 km) target area. Nonetheless, the shallow-set buoy fishery in operation off the Florida coast has provided on average 75 t/year from a small fleet of about 40–50 vessels (NMFS, 2012). The Florida fishery consists predominantly of small vessels (<15 m) with day-trip operations within the coastal waters <50 nmi (NMFS, 2010). The Florida buoy-gear caught product is typically received at higher prices than longline caught swordfish and fulfills a market niche that is similar to that of the west coast harpoon fleet.

In this study, harpoon tagging of swordfish was performed throughout the DSBG deployments, and in many cases provided the criteria for which the set location was determined. The daytime deployment regime and relatively small operation area of DSBG are compatible with modern west coast harpoon operations. Given the valuable market niche that has been developed by the California harpoon fishery, perhaps DSBG can be used to complement and augment California harpoon operations which are severely degraded compared to previous years. Further, given that DGN operations are conducted at night, it may be that DSBG can also be used to augment current DGN operations.

Management Implications

The current decline in California swordfish landings does not align with projected population abundance estimates for the North Pacific swordfish stock (Hinton and Maunder, 2012; Brodziak and Ishimura[2]). Reductions in domestic swordfish landings are more likely a byproduct of increasing regulations geared toward the conservation of protected resources in California waters as well as increasing operational costs for traditional west coast fisheries.

Because domestic swordfish production is unable to meet U.S. consumer demand, the majority of U.S. seafood is imported from foreign nations which often lack comparable management, compliance, and enforcement measures (Rausser et al., 2009). This study provides the initial steps towards identifying new domestic swordfish fishery options for the U.S. west coast while minimizing interactions with species of concern. Similar experiments that expand the gear trials are necessary for better understanding catch rates, potential for bycatch interaction and feasibility of commercial application off the U.S. west coast.

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Emptying the Oceans: A Summary of Industrial Whaling Catches in the 20th Century

ROBERT C. ROCHA, Jr., PHILLIP J. CLAPHAM, and YULIA V. IVASHCHENKO

"Some of the larger factory vessels with their capacity of over 2,500 barrels of oil per day capture more in two days than the original floating factories of 1904 were able to carry away with them in an entire season. One modern factory ship can take more whales in one season than the entire American whaling fleet of 1846 which number over 700 vessels." Lt (j.g.) Quentin R. Walsh, U.S.C.G., 1938

Introduction

In the 1860's, the Norwegian whaler and sealer Svend Føyn introduced the steam-powered whale catcher and the exploding harpoon gun to the whaling industry (Tønnessen and Johnsen, 1982). In the 1870's, he improved upon shore-based factory processing to a level that came to be considered a standard for the industry (Tønnessen and Johnsen, 1982). By the time the 20th century began, the era of modern whaling—at least in the Northern Hemisphere—was well under way.

Sixteen shore whaling stations had been established in Norway by 1883 (Risting, 1922; Dickinson and Sanger, 2005), and others were in operation in Newfoundland, Greenland, Russia, and Japan. In 1903, another Norwegian, Christen Christensen, introduced the first factory ship, the wooden steamship *Telegraf*, into the waters off Spitsbergen (Tønnessen and Johnsen, 1982). Their primary targets were blue, *Balaenoptera musculus;* fin, *B. physalus;* and humpback whales, *Megaptera novaeangliae*.

However, industrial whaling south of the equator did not begin to resemble operations in the north until 5 years into the 20th century. Between 1900 and 1903, the only whales processed industrially were humpbacks caught via net and brought to a shore factory in Whangamumu Bay in New Zealand, a factory that had been established in 1890. The average catch was 8 whales per year during the 20-year operation of this factory (Lillie, 1915; Allison, 2012).

The first shore factory in the Southern Ocean was established in Grytviken (Cauldron Bay) on South Georgia Island by the Norwegian Carl Anton Larsen, from the Compañía Argentina de Pesca, in late 1904 (Tønnessen and Johnsen, 1982). In 1903, one humpback whale was killed by modern methods by Adolf Andresen in the Straits of Magellan, but his processing station was not established until 1905 (Tønnessen and Johnsen, 1982).

Thus, between 1900 and 1908, more whales were captured by industrial whaling methods in the Northern Hemisphere. By 1909, however, whaling south of the equator had surpassed that in the north. This trend continued until 1993, when the catch of whaling operations became comparable in the two hemispheres and were focused largely on minke whales, *Balae-*

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ABSTRACT—Late 19th century technological advances for capturing whales, when combined with the expansion of processing capabilities in the early 20th century, created an industry that could catch and quickly render virtually any whale in any ocean. Here, using the current International Whaling Commission (IWC) database and other sources, we provide the first accounting of the total global catch by industrial whaling operations in the 20th century. In sum, we estimate that nearly 2.9 million large whales were killed and processed during the period 1900–99. Of this total, 276,442 were killed in the North Atlantic, 563,696 in the North Pacific, and 2,053,956 in the Southern Hemisphere.

The years 1925–39 in the Southern Hemisphere and 1946–75 in both hemispheres saw the highest totals of whales killed. For the entire 20th century, the largest catches were of fin, Balaenoptera physalus, *and sperm whales,* Physeter macrocephalus, *with 874,068 and 761,523 taken, respectively; these comprised more than half the total of all large whales taken.*

As noted in other publications, when one species began to decline, another was sought and hunted to take its place. In addition to reported catches, it is now known that the USSR conducted illegal whaling for more than 30 years. The true Soviet catch totals for the Southern Hemisphere were corrected some years ago, and a more recent assessment of the actual number of whales killed by Soviet factory fleet ships in the North Pacific between 1948 and 1979 has provided us with more accurate numbers with which to calculate the overall global catch. The estimate for the total global catch by the USSR is 534,204 whales, of which 178,811 were not reported to the IWC.

noptera acutorostrata, and Antarctic minkes, *B. bonaerensis*.

Until World War I, industrial whaling in the Southern Hemisphere focused primarily on humpbacks. After this, several participating countries (England, Denmark, Norway, Japan, Canada, and the United States in the Northern Hemisphere and South Africa, England, Chile, Norway, and Argentina in the Southern Hemisphere) took full advantage of the previously unexploited stocks of large rorquals (Allison, 2012). These species had not (with the exception of humpbacks) been available to the traditional Yankee whalers, whose small wooden boats could not be rowed fast enough to catch these whales.

The ability of a modern catcher boat to fire exploding harpoons and inject air into these fast-swimming whales (that would have otherwise sunk when they were killed) removed any advantage a whale might have had over a whaling ship. Modern whalers also found new populations of sperm whales, *Physeter macrocephalus,* to hunt and also took southern right whales, *Eubalaena australis,* when they were encountered.

Between the 1920's and the 1980's, industrial whaling went through periods of expansion and crisis. As with many industries, these fluctuations led to international efforts to regulate the use of the primary resource, with varying but usually unsuccessful effect.

In the late 1920's, members of the League of Nations declared that whales needed "urgent international measures" to protect them from extinction and thus set up a committee of experts to find a solution (Redekop, 2010). At the same time, in 1929, Norway adopted its own Norwegian Whaling Act to regulate the annual killing of whales in the open sea and thus (at least in theory) sustain the industry (Tønnessen and Johnson, 1982).

Soon afterward, the League of Nations efforts led to the signing, by 26 countries, of the Convention for the Regulation of Whaling at the Geneva Convention in September 1931. This act entered into force in 1935 (Tønnessen and Johnson, 1982) and served as the first measure of protection for bowhead whales, *Balaena mysticetus;* right whales, *Eubalaena* spp.*;* and gray whales, *Eschrichtius robustus;* all of which had been heavily exploited historically.

Subsequently, the International Agreement for the Regulation of Whaling was signed in London in 1937. However, many parts of this measure were ignored. After World War II, in late 1945, the United States hosted 19 countries at the International Whaling Conference (Tønnessen and Johnson, 1982). Ultimately, this led in 1946 to the creation of the International Convention for the Regulation of Whaling (ICRW) and the governing body for this Convention, the International Whaling Commission (IWC) (IWC, 2002).

Conservation measures were clearly an important part of this document, although protection of whales was undertaken for the strictly commercial purpose of attempting to ensure that the industry remained sustainable. As the Convention worded it, the aim was "to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry."

Industrial whaling resumed in robust fashion in the 1950's, with Norway, Great Britain, Japan, and the USSR hunting in both hemispheres. In the Northern Hemisphere, Canada, Denmark, Iceland, Spain, Portugal, Korea, and China were hunting whales commercially. In the Southern Hemisphere, whaling operations were registered to Brazil, France, South Africa, Australia, Chile, New Zealand, Peru, and Panama, and the Netherlands and Argentina became involved in the region for the first time. A final expansion of Antarctic whaling took place between 1955 and 1961 (Tønnessen and Johnson, 1982).

For much of the 1950's, '60's, and '70's, the number of whales caught by most whaling nations, and the size of those whales, continued to decline. Smaller whale species, discussed later in this paper, were targeted. Japan and the USSR, however, continued to meet their quotas. While some of this was due to having more numerous and more powerful whale catchers, it was also because much of the whaling was being conducted illegally.

The Japanese were catching many undersized whales in their coastal fishery and falsifying their reports in order to conform to IWC regulations (Kasuya, 1999; Kasuya and Brownell, 1999, 2001; Kondo and Kasuya, 2002). Similarly, the USSR is now known to have conducted large-scale illegal catches for more than three decades (Yablokov, 1994; Clapham and Ivashchenko, 2009; Ivashchenko et al., 2013; Ivashchenko and Clapham, 2014). On a much smaller scale, between 1951 and 1956 a factory ship registered in Panama, the *Olympic Challenger*, owned by Aristotle Onassis' Olympic Whaling Company, was consistently "shooting anything that swam and at any time" (Elliot, 1997).

By 1972, more protective attitudes in the United States toward whaling had sufficiently influenced national politics such that both the Marine Mammal Protection Act and the Endangered Species Act were passed within a span of 14 months. In 1972, the United Nations Conference on the Human Environment, held in Stockholm, Sweden, passed a resolution, by 52 votes to 0, calling for a 10-year moratorium on commercial whaling. Similar resolutions were introduced in the IWC in 1972, 1973, and 1974, but the proposal did not receive the required three-fourths majority (IWC, 1975). Nonetheless, by 1982, pro-conservation nations held a substantial majority at the IWC, and duly voted to enact a moratorium (technically a zero-catch limit) on all commercial whaling.

When this vote was taken in 1982, there were 10 countries still in the business of whaling. Iceland, Norway, Spain, Portugal, and Korea were whaling in the north, while Brazil, Peru, Chile, and the USSR were operating in the south. Only Japan still had operations in both hemispheres. The following year whaling operations attributed

to the Philippines were initiated. Research into this endeavor has indicated that Japanese nationals owned and operated all facets of this business, which was terminated in 1986 (Davies, 1986; Barut, 1994; Acebes, 2009). Peruvian whaling had its final season in 1983, and Portuguese whaling ended in 1987 (Allison, 2012).

Once the moratorium took effect with the 1985–86 Antarctic whaling season, all nations, other than Norway, Japan, and the USSR ceased industrial commercial whaling. Japan, Norway, and the USSR all lodged objections to the ban (under the Convention, an objection lodged within 90 days means that the objecting nation is not bound by any decision of the IWC, and this includes the moratorium). However, the Soviets continued whaling for only one more year (Allison, 2012).

Japan initially objected to the moratorium but withdrew this objection under U.S. threat of fisheries sanctions and thereafter exploited Article VIII of the Convention, which permits member states to issue permits to kill whales for scientific research (so-called "scientific whaling," see Clapham, 2014). Iceland, the Republic of Korea, and Norway also received permits for scientific whaling between 1986 and 1994 (IWC, 2004). Iceland withdrew from the IWC in 1992 but subsequently rejoined in 2002, lodged an objection to the Moratorium, and resumed commercial whaling in 2006. Norway halted their scientific whaling and in 1993 also resumed commercial hunting under the objection provision (IWC, 1995).

Remarkably, there has been no complete accounting of the total number of whales taken by industrial whaling in the world's oceans in the 20th century. Clapham and Baker (2008) attempted to assess totals for the Southern Hemisphere, including revised catch totals for the USSR, which, as noted above, conducted extensive illegal whaling after World War II (Clapham and Ivashchenko, 2009; Ivashchenko et al., 2011).

No attempt has previously been made to determine the total catch for the Northern Hemisphere, in part because revised Soviet totals for the North Pacific were not available until very recently (Ivashchenko et al., 2013). Here, using the current IWC database (Allison, 2012), corrected Soviet catch totals, and other sources, we provide an accounting of total catches by all industrial whaling operations worldwide from 1900 to 1999. In addition, we examine trends in the species that were targeted, compare hunt totals and activity between hemispheres, and highlight the periods of most intense hunting.

Materials and Methods

For the purpose of this report, any whale that was processed at a shore whaling station or on a floating factory ship was considered to have been killed by industrial methods. Some whales taken without the use of harpoon cannons, such as those caught by net at Whangamumu Bay in New Zealand, are included in these totals, since they were processed on shore in a factory. The same is true for those caught by traditional methods off the Azores, since they were subsequently towed back to shore-based factories.

All known catches for species caught by subsistence whaling hunts were omitted from the tallies. These include the native operations for humpback whales at St. Vincent and West Greenland, as well as catches of bowhead whales by Alaska natives, and takes of gray whales by the native people of Chukotka (Russia) (Reeves, 2002).

Other species were caught off the coast of West Greenland using the catcher boats *Sonja* and *Sonja Kaligtoq* between 1924 and 1954, and were hand flensed along the coast (Kapel, 1979). Between 1954 and 1958, a shore station in Tovqussaq was used to process whales caught by the *Sonja Kaligtoq* crews (Kapel, 1979). Since then, motorized boats with bow-mounted cannons have been used annually to hunt fin and minke whales (and, more recently, humpback whales). These have been considered aboriginal hunts since 1978, as has a small hunt off East Greenland that began in 1982. These aboriginal kills have also been omitted from the catch totals summarized here. Although the motorized boats sometimes provided access to species that were not part of the traditional aboriginal hunt, the noncommercial use of the whales warrant their omission from our tallies.

Annual totals from the International Whaling Commission database (Allison, 2012) for each of the large whale species listed were tallied for each hemisphere; for the Northern Hemisphere, separate totals were calculated for the North Atlantic and North Pacific. The revised totals for Soviet whale catches in the North Pacific for the period 1948–79, recently compiled by Ivashchenko et al. (2013), were used to replace the Soviet totals in the IWC database.

Catches for North Pacific right whales were compiled from the IWC database (Allison, 2012) and Brownell et al. (2001)[1], with corrections made by one of us (YVI) to reflect the most recent accounting of Soviet illegal catches of this species. Corrected Soviet numbers were published in Ivashchenko and Clapham (2012) and Ivashchenko et al. (2013); however, additional catches have come to light since then, and the total for Soviet takes of this species now stands at 765 (of which only 11 were reported to the IWC; Ivashchenko, unpubl. data).

Revised Soviet data for Bryde's, *B. edeni;* minke, gray, and unspecified/other whales for the years 1948–79 were available only as a sum total and not as annual data. Those totals were included in the final tallying.

The numbers given here are the best estimate of the total catch at this time. New information is continually being added to the IWC database (Allison, 2012), and that database includes ex-

[1]There is a discrepancy between the total numbers of non-Soviet catches of North Pacific right whales reported in the IWC database and those given in Table 3.2 of Brownell et al. (2001), with the latter showing 12 more than the IWC data. Because the Brownell et al. table includes a block of 28 animals taken from 1911 to 1938, with uncertainty noted in this total, we have used the lower IWC figures.

Table 1.—Total catches of large whales by industrial whaling operations, species, and hemisphere, 1900–99.

Species	Catches (no. of animals)			
	North Atlantic	North Pacific	Southern Hemisphere	Total
Blue	6,699	8,838	363,648	379,185
Fin	72,069	75,538	726,461	874,068
Sperm	40,046	314,942	406,535	761,523
Humpback	4,454	29,131	215,848	249,433
Sei	13,048	73,903	204,589	291,540
Bryde's	254	13,795	7,913	21,962
Minke	131,866	34,826	117,213	283,905
Right	141	967	4,452	5,560
Gray	0	3,350	0	3,350
Unspecified/Other	7,865	8,406	7,297	23,568
Sub-total	276,442	563,696		
Hemisphere Totals		840,138	2,053,956	2,894,094

peditions for which no information on catch has been found to date, notably during the early 1900's. Furthermore, it should be noted that Bryde's whales were not distinguished from sei whales until the early 1900's (and often not until much later), and for many years they continued to be listed as sei whales.

Finally, it is important to note that some catch totals for the North Pacific are likely to be incorrect to an unknown degree. The IWC database still contains data from the Japanese coastal fishery that are known to be falsified, notably for sperm whales (Kasuya, 1999); furthermore, analyses of sperm whale length data have raised suspicions about the reliability of the pelagic Japanese catch statistics for this species (Cooke et al., 1983). We currently have no way of estimating the degree of unreliability in these data, and North Pacific totals for sperm whales are reported with that caveat.

Results and Discussion

The technological advances of the late 19th century, when combined with the expansion of processing capabilities in the early 20th century, created an industry that could essentially catch and quickly process any whale in any ocean. In total, the years from 1900 through 1999 saw nearly 2.9 million large whales killed and processed globally by industrialized whaling. Total catches by species and hemisphere are summarized in Table 1. Tables 2 and 3 break down catches for each hemisphere by 10-year periods, and trends in catches for each species are graphically represented in Figures 1a and 1b. More detail is provided in Tables 4 and 5, which give catch totals by species and by year for the Northern and Southern Hemispheres, respectively.

Fin whales were killed in larger numbers (874,068) than any other species, with sperm whales (761,523) being the second-most hunted. Together, these two whales comprise more than half (56.5%) of the large cetacean species killed globally in the 20th century. This proportion is almost the same (55.1%) when looking at the numbers for only the Southern Hemisphere. In the Northern Hemisphere, the sperm whale was the most heavily hunted (354,988 catches)[2], followed by the minke whale and the fin whale.

[2]This number for sperm whales is likely an underestimate because of the known unreliability of Japanese coastal whaling statistics, as noted above, together with the possibility that Japanese pelagic catch statistics are also unreliable to an unknown degree.

Table 2.—Northern Hemisphere industrial whaling totals, including illegal Soviet whaling, by decade, 1900–99 (Soviet data for which only sum totals are available are not included).

Species	1900–1909	1910–1919	1920–1929	1930–1939	1940–1949	1950–1959	1960–1969	1970–1979	1980–1989	1990–1999
Blue	4,830	3,040	2,738	1,126	554	1,483	1,731	35	0	0
Fin	12,570	18,548	23,977	12,599	11,931	25,137	30,824	9,769	2,252	0
Sperm	294	3,449	7,512	11,793	21,666	64,092	153,193	82,429	4,960	0
Humpback	4,409	7,437	8,005	2,513	923	2,538	7,700	60	0	0
Sei	2,903	6,460	7,677	5,446	5,255	10,941	33,439	14,253	577	0
Bryde's	0	0	20	4	418	934	480	4,940	3,786	1
Minke	0	38	156	7,578	23,752	38,976	36,929	37,550	17,606	3,418
Gray	0	1,057	550	747	480	28	339	0	0	0
Right	92	72	88	46	35	84	676	15	0	0
Unspec.	11,212	2,153	147	2,250	43	299	4	5	13	0
Total	36,310	42,254	50,870	44,102	65,057	144,512	265,315	149,056	29,194	3,419

Table 3.—Southern Hemisphere industrial whaling totals, by decade, 1900–1999.

Species	1900–1909	1910–1919	1920–1929	1930–1939	1940–1949	1950–1959	1960–1969	1970–1979	1980–1989	1990–1999
Blue	758	30,263	84,319	163,687	40,389	29,149	13,696	1,387	0	0
Fin	1,070	36,753	66,084	137,490	100,705	262,404	111,776	10,178	1	0
Sperm	11	4,122	6,609	21,540	34,888	96,997	141,754	99,735	879	0
Humpback	11,603	57,205	14,090	31,758	11,105	58,849	31,195	43	0	0
Sei	661	2,549	6,373	2,333	4,305	21,302	131,538	35,528	0	0
Bryde's	3	607	322	57	450	252	1,619	3,577	1,026	0
Minke	0	6	1	0	1	132	3,196	64,152	45,974	3,751
Right	331	487	119	122	2	250	3,137	4	0	0
Unspec.	1,363	3,311	313	2,198	87	15	9	1	0	0
Totals	15,800	135,303	178,230	359,185	191,932	469,350	437,920	214,605	47,880	3,751

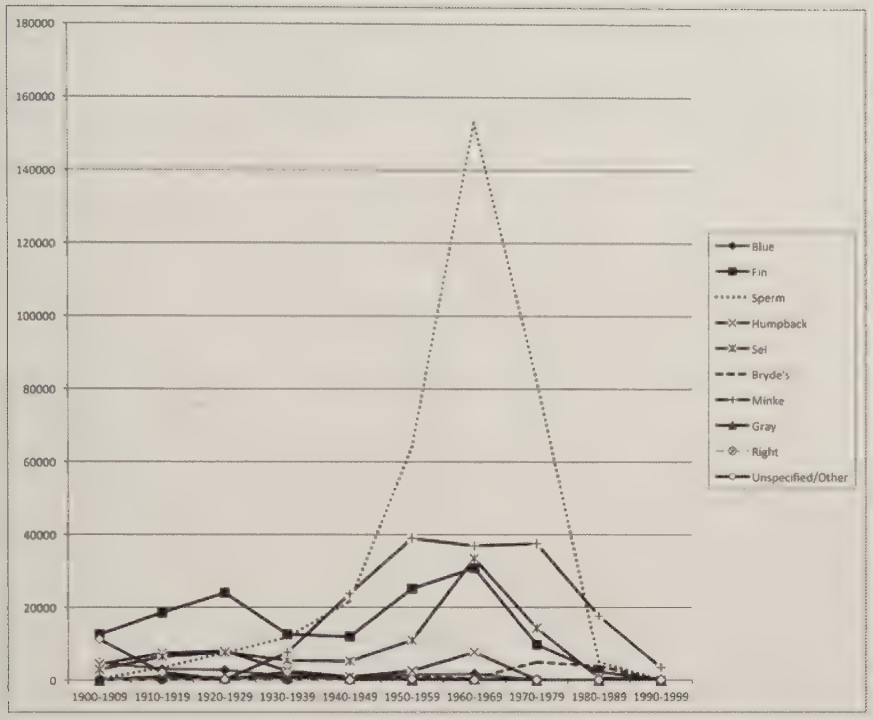

Figure 1a.—Northern Hemisphere industrial whaling totals, including Soviet whaling, by decade, 1900–99 (data from Table 2).

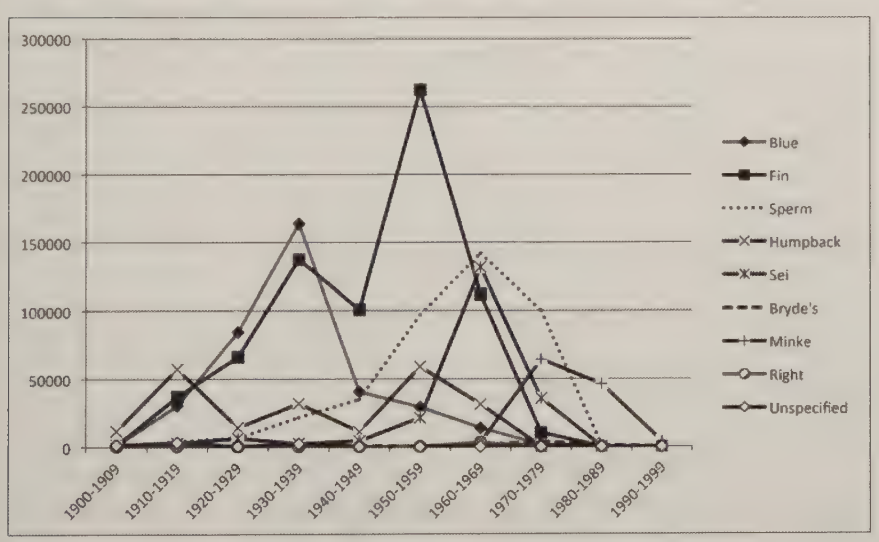

Figure 1b.—Southern Hemisphere industrial whaling totals, by decade, 1900–99 (data from Table 3).

The year 1925 marked the arrival in the Antarctic of the first modern pelagic stern-slip factory ship, the British vessel *Lansing* (Clapham and Baker, 2008). The ability to quickly process large numbers of whales in habitats far offshore greatly increased the efficiency of the industry. Beginning in 1927, industrial whalers were consistently killing more than 20,000 whales annually in the Southern Hemisphere (they had surpassed this total in 1912, 1913, and 1925). Only a 1-year cessation of whaling by Norway, in 1931, brought the total below 20,000. Between 1934 and 1939 more than 34,000 whales were killed each year. The onset of World War II and the repurposing of resources led to a 6-year period of reduced whaling. However, once the war ended, the business of hunting whales resumed.

Twentieth century whaling was far more intense in the Southern Hemisphere (though no less devastating to some populations north of the equator): the number of whales killed in the Southern Hemisphere was 2.5 times greater than in the Northern. Over the three decades following World War II, the most intensive 5-year period for whaling in the Southern Hemisphere was 1957–61, when 280,133 whales were killed and processed. By contrast, the most intensive 5-year span for whales in the north was 1966–70, when 153,722 whales were killed. The year 1960 had the highest regional 1-year total for the century, with 62,129 animals killed in the Southern Hemisphere. In the north, the highest 1-year total was 33,473 whales in 1966.

Taken together, the global total for the years 1957–61 was 368,878 large whales. The 3 highest years were 1959–61, with each of those 3 years having global totals approaching or exceeding 75,000 whales. A further 69,466 were killed in 1964.

The trends in the numbers highlighted here, whether by hemisphere (Fig. 1a, b) or globally, echo prior analyses of catch numbers and related economics. As stated by Schneider and Pearce (2004), "Analysis of the data reveals a

Table 4.—Northern Hemisphere industrialized whaling catches, including corrected Soviet data (1948–79). Data from C. Allison, IWC summary catch database Version 5.3, Date: 25 October 2012, Areas: North Atlantic and Arctic, North Pacific, Japan and Korea, and Ivashchenko et al. Soviet North Pacific catches 2012. Annual totals exclude all Soviet data for North Pacific right whales.

	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1900-1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1910-1919	Total
Blue	381	299	142	492	862	1,002	477	391	412	372	4,830	336	577	605	248	400	174	164	235	140	161	3040	7,870
Fin	502	570	673	988	1945	1,882	1,179	1,365	1,576	1890	12,570	1,731	2,705	2,112	1,905	2,661	1,735	1,444	1,045	1,724	1,486	18,548	31,118
Sperm	0	8	2	152	13	11	10	16	13	69	294	78	238	178	204	380	312	438	278	729	614	3,449	3,743
Humpback	131	308	423	722	697	323	323	293	510	679	4,409	888	1,296	1,135	773	1,043	594	455	350	306	597	7,437	11,846
Sei	40	29	58	106	176	136	473	476	646	763	2,903	503	581	390	567	554	731	461	728	1,027	918	6,460	9,363
Bryde's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	0	6	7	14	38	38
Gray	0	0	0	0	0	0	0	0	0	0	0	0	122	193	132	174	139	78	69	104	46	1,057	1,057
Right	0	0	2	2	2	0	6	25	28	27	92	19	3	13	3	7	8	9	2	3	5	72	164
Unspecified/Other	597	1,029	1,643	966	651	747	1,033	2,140	1,478	928	11,212	1,304	185	319	27	83	0	61	0	104	70	2,153	13,365
	1,651	2,243	2,943	3,428	4,346	4,101	3,501	4,706	4,663	4,728	36,310	4,859	5,707	4,945	3,859	5,303	3,703	3,110	2,713	4,144	3,911	42,254	78,564

	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1920-1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1930-1939	Total
Blue	242	60	163	174	261	321	351	257	500	409	2,738	237	75	157	86	94	172	85	123	56	41	1,126	3,864
Fin	1,653	1,019	1,864	2,606	3,183	3,733	3,638	2,464	2,070	1,747	23,977	1,729	879	1,033	1,373	1,167	981	1,118	2,005	1,077	1,237	12,599	36,576
Sperm	424	387	840	712	640	780	937	783	1,012	997	7,512	1,001	368	470	903	961	1,132	1,566	1,865	1,618	1,909	11,793	19,305
Humpback	790	331	993	933	624	1,085	1,135	1,218	556	340	8,005	331	109	229	302	292	374	271	263	121	221	2,513	10,518
Sei	1,081	565	552	801	961	944	858	790	538	587	7,677	571	478	455	421	488	511	506	622	658	736	5,446	13,123
Bryde's	0	0	0	0	0	2	18	0	0	0	20	0	0	0	0	0	0	0	0	0	4	4	24
Minke	6	20	20	20	20	20	13	13	9	15	156	60	194	369	546	731	908	1,078	1,283	1,422	987	7,578	7,734
Gray	68	116	49	27	18	142	53	42	21	14	550	30	11	17	106	154	144	188	14	54	29	747	1,297
Right	5	8	5	11	11	10	10	10	11	7	88	2	8	20	4	0	2	0	6	0	0	42	130
Unspecified/Other	41	11	13	20	0	44	18	0	0	0	147	300	3	0	5	506	615	613	0	208	0	2,250	2,397
	4,310	2,517	4,499	5,304	5,718	7,081	7,031	5,577	4,717	4,116	50,870	4,261	2,125	2,750	3,746	4,393	4,839	5,425	6,181	5,214	5,164	44,098	94,968

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1940-1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1950-1959	Total
Blue	53	79	20	16	7	27	46	66	142	98	554	73	125	147	157	223	155	161	154	132	156	1,483	2,037
Fin	867	1,134	767	734	898	847	1,419	1,459	2,037	1,769	11,931	1,992	2,053	1,886	1,836	2,697	2,718	2,719	3,084	3,224	2,928	25,137	37,068
Sperm	2,378	2,388	1,325	1,821	1,748	1,050	2,187	2,420	3,046	3,303	21,666	4,073	4,943	4,557	4,681	5,331	6,539	7,800	8,593	9,008	8,567	64,092	85,758
Humpback	201	81	72	116	75	21	36	38	170	113	923	147	103	131	122	286	195	256	330	495	473	2,538	3,461
Sei	432	692	308	399	789	108	556	405	643	923	5,255	420	759	960	975	1,180	962	1,154	969	1,651	1,911	10,941	16,196
Bryde's	0	0	0	0	0	0	29	158	115	116	418	243	280	411	0	0	0	0	0	0	0	934	1,352
Minke	727	2,365	2,459	1,911	1,610	1,878	2,013	2,716	3,893	4,180	23,752	2,275	3,195	3,898	2,931	3,952	4,840	4,338	4,444	5,265	3,838	38,976	62,728
Gray	105	57	101	99	6	58	22	31	0	1	480	0	1	0	10	0	0	0	0	8	9	28	508
Right	1	5	6	13	3	1	0	0	1	0	30	0	1	0	0	0	0	2	0	0	1	4	34
Unspecified/Other	8	0	0	0	0	35	0	0	0	0	43	0	0	49	29	82	98	28	13	0	0	299	342
	4,772	6,801	5,058	5,109	5,136	4,025	6,308	7,293	10,047	10,503	65,052	9,223	11,460	12,039	10,741	13,751	15,507	16,458	17,587	19,783	17,883	144,432	209,484

Table continued

Table 4.—*continued*

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1960-1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1970-1979	Total
Blue	86	92	150	605	254	279	61	97	56	51	1,731	20	8	0	1	0	0	1	2	3	0	35	1,766
Fin	2,946	2,421	2,651	3,725	4,816	3,480	3,195	3,040	2,497	2,053	30,824	1,839	1,424	1,464	822	875	558	561	430	945	851	9,769	40,593
Sperm	8,711	8,230	8,581	13,171	13,093	18,405	23,017	20,890	18,967	20,128	153,193	16,131	11,974	6,977	7,036	8,805	8,508	7,798	6,696	4,861	3,643	82,429	235,622
Humpback	298	526	1,920	2,722	1,450	538	82	106	46	12	7,700	28	21	0	0	10	0	1	0	0	0	60	7,760
Sei	1,294	1,025	2,216	2,680	3,789	3,291	3,824	5,208	5,073	5,039	33,439	3,966	3,221	2,638	2,004	1,336	699	13	139	139	98	14,253	47,692
Bryde's	0	0	196	0	0	0	2	22	171	89	480	73	281	130	73	705	804	972	721	380	801	4940	5,420
Minke	3,991	3,856	3,987	4,083	3,796	3,391	3,232	3,266	3,795	3,532	36,929	3,812	3,764	4,497	3,930	3,525	3,543	4,055	3,612	3,288	3,524	37,550	74,479
Gray	9	4	4	2	20	4	57	99	66	74	339	0	0	0	0	0	0	0	0	0	0	0	339
Right	0	3	3	3	0	0	0	0	2	0	11	0	0	0	2	1	0	0	1	0	0	4	15
Unspecified/Other	0	0	0	0	0	0	3	1	0	0	4	0	0	1	0	0	0	0	0	4	0	5	9
	17,335	16,157	19,708	26,991	27,218	29,388	33,473	32,729	30,673	30,978	264,650	25,869	20,693	15,707	13,868	15,257	14,112	13,401	11,601	9,620	8,917	149,045	413,695

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1980-1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	1990-1999	Total
Blue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fin	459	404	347	269	271	210	76	80	68	68	2,252	0	0	0	0	0	0	0	0	0	0	0	2,252
Sperm	1,517	1,163	621	414	454	400	200	191	0	0	4,960	0	0	0	0	0	0	0	0	0	0	0	4,960
Humpback	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sei	103	100	71	100	95	38	40	20	10	0	577	0	0	0	0	0	0	0	0	0	0	0	577
Bryde's	755	485	482	545	528	357	317	317	0	0	3,786	0	0	0	0	0	0	0	0	1	0	1	3,787
Minke	3,557	3,212	3,391	2,848	1,753	1,365	759	673	29	19	17,606	0	1	95	226	280	318	465	617	725	691	3,418	21,024
Gray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Right	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unspecified/Other	3	4	3	3	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	13
	6,394	5,368	4,915	4,179	3,101	2,370	1,392	1,281	107	87	29,194	0	1	95	226	280	318	465	617	726	691	3,419	32,613

Soviet numbers for right whales not entered into decades

	1900-1919	1920-1939	1940-1959	1960-1979	1980-1999	Totals	Addl Soviet	Total All
Blue	7,870	3,864	2,037	1,766	0	15,537		15,537
Fin	31,118	36,576	37,068	40,593	2,252	147,607		147,607
Sperm	3,743	19,305	85,758	235,622	4,960	349,388	5,600	354,988
Humpback	11,846	10,518	3,461	7,760	0	33,585		33,585
Sei	9,363	13,123	16,196	47,692	577	86,951		86,951
Bryde's	0	24	1,352	5,420	3,787	10,583	3,466	14,049
Minke	38	7,734	62,728	74,479	21,024	166,003	689	166,692
Gray	1,057	1,297	508	339	0	3,201	149	3,350
Right	164	130	34	15	0	343	765	1,108
Unspecified/Other	13,365	2,397	342	9	13	16,126	145	16,271
	78,564	94,968	209,484	413,695	32,613	829,324	10,814	840,138

Soviet numbers for right whales entered into decades

	1900-1919	1920-1939	1940-1959	1960-1979	1980-1999	Totals	Addl Soviet	Total All
Blue	7,870	3,864	2,037	1,766	0	15,537		15,537
Fin	31,118	36,576	37,068	40,593	2,252	147,607		147,607
Sperm	3,743	19,305	85,758	235,622	4,960	349,388	5,600	354,988
Humpback	11,846	10,518	3,461	7,760	0	33,585		33,585
Sei	9,363	13,123	16,196	47,692	577	86,951		86,951
Bryde's	0	24	1,352	5,420	3,787	10,583	3,466	14,049
Minke	38	7,734	62,728	74,479	21,024	166,003	689	166,692
Gray	1,057	1,297	508	339	0	3,201	149	3,350
Right	164	134	120	690	0	1,108		1,108
Unspecified/Other	13,365	2,397	342	9	13	16,126	145	16,271
	78,564	94,972	209,570	414,370	32,613	830,089	10,049	840,138

Table 5.—Southern Hemisphere industrialized whaling catches data from: C. Allison. IWC Summary catch database Version 5.3, Date: 25 Oct. 2012 Areas; South Pacific, South Atlantic, Indian Ocean, Southern Hemisphere.

	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1900-1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1910-1919	Total
Blue	0	0	0	0	11	51	68	106	310	212	758	365	1,292	2,590	3,112	5,376	5,702	4,441	3,159	2,219	2,007	30,263	31,021
Fin	0	0	0	0	4	104	93	122	310	437	1,070	721	2,034	5,132	5,707	4,897	6,150	2,956	2,265	3,203	3,688	36,753	37,823
Sperm	0	0	0	0	0	3	1	0	1	6	11	0	20	480	525	681	766	684	191	224	551	4,122	4,133
Humpback	8	8	8	9	188	319	449	1,399	3,422	5,793	11,603	10,201	11,830	11,185	10,553	7,605	3,888	744	316	340	543	57,205	68,808
Sei	0	0	0	0	0	97	0	0	218	346	661	225	38	175	1,055	398	98	99	109	105	247	2,549	3,210
Bryde's	0	0	0	0	0	0	0	0	0	3	3	0	73	187	126	51	96	26	0	32	16	607	610
Minke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	0	6	6
Right	0	0	0	0	0	16	81	93	68	73	331	99	107	23	78	25	36	20	60	18	21	487	818
Unspecified	0	0	0	0	0	130	428	520	46	239	1363	734	1,287	419	261	0	140	470	0	0	0	3,311	4,674
Total	0	8	8	9	203	720	1,120	2,240	4,375	7,109	15,800	12,345	16,681	20,191	21,417	19,033	16,877	9,440	6,105	6,141	7,073	135,303	151,103

	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1920-1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1930-1939	Total
Blue	3,023	4,637	6,787	4,926	6,714	6,196	8,663	10,278	14,333	18,762	84,319	30,490	6,657	19,023	17,456	16,625	17,892	14,670	15,174	14,175	11,525	163,687	248,006
Fin	5,924	2,787	4,339	3,914	5,364	10,173	7,019	5,953	7,708	12,903	66,084	11,171	3,336	5,517	7,824	13,228	10,294	15,865	29,446	21,479	19,330	137,490	203,574
Sperm	409	422	250	299	437	807	743	808	1,096	1,338	6,609	676	197	454	1,084	1,246	1,191	4,149	5,621	3,964	2,958	21,540	28,149
Humpback	567	370	1,710	1,572	1,420	2,686	1,878	1,345	1,408	1,134	14,090	1,441	418	506	1,089	3,283	4,906	8,806	7,206	3,810	293	31,758	45,848
Sei	107	150	143	390	672	404	1,255	1,343	1,447	462	6,373	358	44	35	26	324	187	803	285	133	138	2,333	8,706
Bryde's	17	0	3	11	84	29	60	31	60	27	322	14	0	0	0	0	0	7	36	0	0	57	379
Minke	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Right	16	8	4	15	11	17	26	6	4	12	119	4	0	23	14	17	30	4	8	15	7	122	241
Unspecified	43	0	0	0	0	0	0	260	0	10	313	0	0	0	0	200	44	0	1	4	1,949	2,198	2,511
Total	10,106	8,375	13,236	11,127	14,702	20,312	19,644	20,024	26,056	34,648	178,230	44,154	10,652	25,558	27,493	34,923	34,544	44,304	57,777	43,580	36,200	359,185	537,415

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1940-1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1950-1959	Total
Blue	4,975	65	127	349	1,050	3,647	9,237	6,968	7,731	6,240	40,389	7,107	5,202	4,005	2,888	2,535	1,739	1,715	1,769	1,251	938	29,149	69,538
Fin	8,168	1,382	980	1,459	1,953	9,429	14,970	21,766	19,962	20,636	100,705	20,160	23,920	23,945	28,568	28,833	27,734	28,374	27,817	27,469	25,584	262,404	363,109
Sperm	1,366	2,563	3,543	3,755	860	1,062	2,431	6,788	8,179	4,341	34,888	6,318	15,852	4,015	5,377	12,605	10,126	8,255	12,318	11,541	10,590	96,997	131,885
Humpback	2,967	181	227	174	263	461	249	253	461	5,869	11,105	5,621	4,788	3,492	2,952	4,067	6,168	3,149	4,774	8,065	15,773	58,849	69,954
Sei	139	57	86	231	102	119	469	810	788	1,504	4,305	1,157	1,642	1,852	1,576	827	906	1,955	3,615	3,076	4,696	21,302	25,607
Bryde's	0	0	0	0	0	0	0	55	238	157	450	100	23	0	7	0	0	14	36	29	43	252	702
Minke	0	0	0	0	0	0	0	0	0	1	1	0	4	6	12	0	36	45	13	11	5	132	133
Right	0	0	0	1	0	0	1	0	0	0	2	0	22	9	17	34	18	49	19	3	79	250	252
Unspecified	26	0	0	0	0	0	31	12	17	1	87	6	0	0	0	0	1	0	8	0	0	15	102
Totals	17,641	4,248	4,963	5,969	4,228	14,718	27,388	36,652	37,376	38,749	191,932	40,469	51,453	37,324	41,397	48,901	46,728	43,556	50,369	51,445	57,708	469,350	661,282

Table continued

Table 5.—*Continued.*

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1960-1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1970-1979	Total
Blue	1,743	1,145	1,748	1,508	3,349	1,477	665	461	674	926	13,696	835	544	7	1	0	0	0	0	0	0	1,387	15,083
Fin	27,299	27,085	17,910	14,218	7,957	3,931	3,882	2,603	3,760	3,131	111,776	3,422	2,324	1,822	1,341	1,026	233	8	2	0	0	10,178	121,954
Sperm	11,757	14,458	15,884	21,814	20,610	12,631	13,073	9,911	9,323	12,293	141,754	12,632	17,073	13,311	12,708	14,038	10,797	6,666	6,026	5,681	803	99,735	241,489
Humpback	14,902	7,210	3,744	844	270	2,195	1,096	928	5	1	31,195	0	3	5	4	4	8	4	4	11	0	43	31,238
Sei	6,409	7,195	6,962	10,903	21,964	21,298	17,611	16,412	11,679	11,105	131,538	9,431	7,466	4,373	4,926	4,406	2,272	1,898	590	101	65	35,528	167,066
Bryde's	10	23	73	139	681	428	151	73	8	33	1,619	19	486	8	317	467	434	623	506	417	300	3,577	5,196
Minke	3	3	19	120	63	81	389	1,118	630	770	3,196	915	4,162	6,583	8,541	8,037	7,185	8,676	6,000	6,156	7,897	64,152	67,348
Right	6	1,355	727	374	82	350	161	4	0	78	3,137	2	2	0	0	0	0	0	0	0	0	4	3,141
Unspecified	0	8	0	0	0	1	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	1	10
Totals	62,129	58,482	47,067	49,920	54,976	42,392	37,028	31,510	26,079	28,337	437,920	27,257	32,060	26,109	27,838	27,978	20,929	17,875	13,128	12,366	9,065	214,605	652,525

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1980-1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	1990-1999	Total
Blue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fin	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Sperm	574	289	0	0	0	0	9	7	0	0	879	0	0	0	0	0	0	0	0	0	0	0	879
Humpback	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bryde's	211	162	320	333	0	0	0	0	0	0	1,026	0	0	0	0	0	0	0	0	0	0	0	1,026
Minke	7,142	7,903	7,301	6,680	5,568	5,567	4,969	273	241	330	45,974	327	288	330	330	330	440	440	438	389	439	3,751	49,725
Right	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unspecified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	7,927	8,354	7,621	7,014	5,568	5,567	4,978	280	241	330	47,880	327	288	330	330	330	440	440	438	389	439	3,751	51,631

	1900-1919	1920-1939	1940-1959	1960-1979	1980-1999	Totals
Blue	31,021	248,006	69,538	15,083	0	363,648
Fin	37,823	203,574	363,109	121,954	1	726,461
Sperm	4,133	28,149	131,885	241,489	879	406,535
Humpback	68,808	45,848	69,954	31,238	0	215,848
Sei	3,210	8,706	25,607	167,066	0	204,589
Bryde's	610	379	702	5,196	1,026	7,913
Minke	6	1	133	67,348	49,725	117,213
Right	818	241	252	3,141	0	4,452
Unspecified	4,674	2,511	102	10	0	7,297
	151,103	537,415	661,282	652,525	51,631	2,053,956

whaling cycle very much as would be expected for an open-access marine resource that is initially abundant but which then gets successively overexploited, species by species."

As one species began to dwindle in abundance, another would be targeted to take its place, and typically the species that was the next size smaller. Between 1921 and 1935, blue whales (with the exception of 1925) were the primary species taken in the Southern Hemisphere, with fin whales consistently second (Fig. 1b). After 1935, as blue whale numbers decreased, not only did fin whales become the primary species, but the annual totals for this species were consistently 2.0–2.5 times higher than those of the previous 15 years. Given that two fin whales were considered, in terms of oil yield, the equivalent of one blue whale (as measured by the "Blue Whale Unit" introduced by the IWC in 1932; Schneider and Pearce, 2004), this doubling of fin whale captures helped to maintain a consistent level of production.

In 1963, the sperm whale became the most-hunted species. At this same time, however, the number of sei whales captured exceeded 10,000. This was also the last year that fin whales were taken above the 10,000 level. For the next 5 years the sei whale was the primary target until their catch numbers dropped below 10,000 a year. Sperm whales again were the preferred species from 1969 to 1975, with kills consistently exceeding 10,000 per annum. No species of baleen whale exceeded the 10,000 level after 1969. Since 1978, most of the whales caught south of the equator have been Antarctic minkes, a great many of them as a result of Japanese scientific whaling (Clapham, 2014).

Although industrial whaling in the Northern Hemisphere was conducted on a smaller scale, similar patterns can be seen for several species (Table 1, 2; Fig. 1a). The cycle is most noticeable when considering the timing of the decline in fin and sei whale catches in the mid-1960's, and the effort made after 1970 to replace them with Bryde's whales, a species that had been largely ignored until that time (although as noted above they were often mistaken for sei whales in earlier catches).

The other noticeable replacement in targeted species was seen for humpback and sei whales, which, between 1908 and 1932, consistently alternated between second and third place in catch totals. After 1933, minke whales became the second-most hunted baleen whale north of the equator, and humpback captures continued to decline. After 1940, minkes replaced fin whales as the primary mysticete target of whalers.

One noticeable hemispheric difference in the order in which species were hunted is how much earlier minkes were targeted in the Northern Hemisphere. By 1932, minkes were being hunted as consistently as sperm, humpback, and sei whales. This also coincided with the drop in blue whale catches that began in 1932. While not nearly as lucrative as blue whales, minkes were much more abundant, and they were routinely caught in numbers greater than 3,000 annually from after World War II until 1983. By contrast, minkes were not a significant focus of whaling efforts in the Southern Hemisphere until 1967.

Before the global moratorium was passed by the IWC in 1982, whaling nations had agreed to institute bans on whaling of certain species, beginning with the cessation of commercial bowhead whaling in 1931. Other bans went into effect for right and gray whales in 1935, humpback whales in the North Atlantic in 1955, blue whales in 1966, and fin whales in the Southern Hemisphere and North Pacific in 1976 (IWC, 1977).

However, despite those bans, hunting of these species continued. The recent emergence of reliable data regarding the extent of illegal whaling conducted by the USSR between 1948 and 1979 has made clear how much poaching took place (Yablokov, 1994; Clapham and Ivashchenko, 2009; Ivashchenko et al., 2011, 2013). The estimate for the total global catch by the USSR is 534,204 whales, of which 178,811 were not reported to the IWC.[3] This new information has also shed light on the previously unexplained population decline and failure to recover of the North Pacific right whale, *Eubalaena japonica* (Ivashchenko and Clapham, 2012).

A review of annual entries in the IWC database provides evidence that other countries participated in the killing of whales after various bans were issued. Ships registered in Argentina, Brazil, Canada, Chile, Germany, Japan, Netherlands, Norway, Portugal, South Africa, and the United Kingdom killed a total of 103 right whales after 1935 (Allison, 2012). After 1966, another 87 blue whales were killed by ships registered in Denmark, South Africa, Australia, Chile, Japan, and Spain (Allison, 2012). Two of the ships registered in Spain, the *Sierra* and the *Tonna*, were actually pirate whaling ships that were not registered with an IWC nation but whose operations were linked to Japan (Clapham and Baker, 2008). Korean vessels took 84 fin whales in the North Pacific between 1977 and 1985.

Ninety-eight percent of the blue whales killed globally after the ban in 1966 were killed by Soviet whalers, as were 92% of the 1,201 humpbacks killed commercially between 1967 and 1978. The majority of these, 1,034, were killed in 1967. Of the 512 gray whales killed after 1947, 309 (60%) were killed by the United States through permits issued for scientific whaling.

Conclusion

Remarkably, despite the importance of industrial whaling to several economies and more recently as a symbol of human misuse of the world's resources, there has until now been no attempt to estimate the total catch for the 20th century, although Clapham and Baker (2008) provided estimates for the Southern Hemisphere. Here, taking advantage of newly revised catch figures for Soviet

[3]These figures include an additional 85 North Pacific right whales that were not included in the totals given by Ivashchenko and Clapham (2014).

whaling in both the Southern Ocean and the North Pacific, we have provided a tally of the total number of whales killed since full-scale modern industrial whaling began shortly after 1900. That total is close to three million animals, making it (at least in terms of sheer biomass) perhaps the largest hunt in human history.

Between 1712 and 1899 it is estimated that 300,000 sperm whales were killed globally by crews on sailing vessels that used small boats to chase, harpoon, tire out, and lance them (Smith et al., 2008). The same process applied to the slower mysticetes; the primary product from sperm whales was oil, and for baleen whales, oil, and baleen.

The industrial process was much more efficient. Separate crews focused on either catching or processing, and both had the advantage of mechanization to greatly increase the speed of these operations. Between 1900 and the middle of 1962, the same number of sperm whales had been killed by industrial methods as had been taken during the 18th and 19th centuries. Astonishingly, this feat was then repeated between 1962 and 1972.

The International Whaling Commission was a body initially created in 1946 to manage hunting for the sake of the industry, not that of the whales. By the time the IWC voted in 1982 to implement a moratorium on whaling beginning in 1985, at least 2,870,291 whales (99.1% of the overall 20th century total of 2,894,094) had been killed by industrial whaling methods. As a result, many populations had been reduced to small fractions of their pristine abundance.

Southern Ocean blue whales, for example, are estimated to be at less than 1% of their prewhaling numbers (Branch et al., 2007). In addition, some populations of whales appear to have been completely extirpated (Clapham et al., 2008) or, in the case of eastern North Pacific right whales, nearly so (Ivashchenko et al., 2013). To paraphrase a famous quotation by John Gulland regarding fisheries: whaling management in the 20th century was an interminable debate about the status of stocks until all doubt was removed. And so were most of the whales.

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Editorial Guidelines for the *Marine Fisheries Review*

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